FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Developing Exhaust Air Energy Recovery Credits for the Florida Energy Code

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Table of Contents

List of Figures

List of Tables

Nomenclature:

CAV	constant air volume
CC	cooling coil
CRAC	computer room air conditioner
CW	chilled water cooling type
DOAS	dedicated outdoor air system
DOE	united states department of energy
DX	direct expansion
E	annual HVAC energy use of a standard reference building
EF	electric furnace
ERV	energy recovery ventilator
EA	exhaust air
ERR	energy recovery ratio, (W/W)
EUI	energy use intensity, $kBtu/hr/ft^2$
FFF	fossil fuel furnace
GF	gas furnace
HWFFB	hot-water fossil fuel boiler
HC	heating coil
HRV	heat recovery ventilation
HVAC	heating ventilation and air conditioning
IDF	input definition file for energy plus
OA	outdoor air
OA Mixer	outdoor air mixer
PSZ-AC	packaged single zone air conditioner
PSZ-HP	packaged single zone heat pump
PTAC	packaged terminal air conditioner
PVAV	Packaged variable air volume system with Reheat
ΔP	pressure drop across an ERV device
RA	return air
SA	supply air
VAV	variable air volume system with reheat

Symbols

ε	cooling and heating effectiveness of ERV devices

Subscripts:

wERV	modeling with ERV device included
woERV	modeling without ERV device included

1 Introduction

Exhaust air energy recovery process conditions outdoor air by transferring energy to or from the outdoor air stream using an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) device. In the process the outdoor air is cooled and dehumidified in cooling season or the outdoor air is heated and humidified during the heating season. Here after an ERV stands for both ERV and HRV unless specifically stated otherwise. Several previous studies have shown that energy saving potential of an ERV device depends on design and operational parameters, and weather locations.

Dieckmann, et al. (*2003*) claims that ERV device can reduced peak cooling capacity by up to one-third depending on climate and outdoor air amount. *Christman et al.*, (*2009*) have shown that the ERV energy savings potential is strongly dependent on the amount of outdoor air. *Fan et al*. (*2014*) reported that field measured energy use savings due to ERV was approximately 30.0% in winter and 20.0% in summer for a two story office building in Gifu prefecture, Japan. They also reported that the heating and cooling load due to outdoor air was reduced by 60% and 70%, respectively. *Boody (1997)* reported that ERV installed in 85,327 ft^2 (7,927 m^2) office, laboratory and manufacturing facility located in High Point, North Carolina reduced the heating and cooling design load by 41.4% and 56.8%, respectively. Run around heat recovery heat exchanger at 50% total effectiveness can reduce the outside air design cooling load by 13.0% for outdoor air design condition of 92.0°F and 74.0°F wet-bulb temperature and design exhaust air condition of 75.0°F and 50% relative humidity (*Paarporn, 1999*). He also reported that the annual cooling and heating energy use reduction using Modified Bin method was about 28.9%. *Bartholomew* (*2004*) reported that the ERV device installed in outdoor air system would operate with energy recovery ratio (*ERR*) of 64.9 W/W in winter. *Wang, et al*. *(2012)* demonstrated that using computer simulation for medium size office building annual energy savings due to ERV device ranges 10% – 15% in Miami, Florida climate depending on the design effectiveness values. A simulation study conducted in high rise residential building in South Korea showed that HRV device can save 8.8% and 9.45% of annual cooling and heating energy, respectively (*Kim et al*., *2012*). Experimental measurement conducted to validate the simulation results also showed that during continuous operation over three days period, the HRV device in summer and winter reduced the cooling and heating energy use by 13.0% and 21.0%, respectively. ERV device can also be used to adjust the sensible heat ratio of the cooling coil for improved dehumidification (*Dieckmann, 2008*). In hot and humid climate, about 58% of the energy required for pre-treating outdoor air can be recovered using membrane based ERV device (*Niu and Zhang, 2001*).

The purpose of this project is to determine ERV credits that can be used to estimate the energy savings potential of energy recovery devices relative to standard reference building annual HVAC energy uses in Florida climate for incorporation in the Florida Code. The ERV credits represent the annual HVAC energy savings in percent relative to a standard reference building HVAC energy use. The reference building HVAC energy use is a standard reference building based on the 2014 Florida Code (*Florida Building Code, 2014*) without ERV device. The proposed building is a standard reference building with ERV device installed. The energy savings potential due to ERV device is determined using computer simulations. The pre-determined ERV credits then will be used for commercial code compliance calculation when the compliance software cannot model ERV devices. The DOE's whole building energy simulation program, EnergyPlus, version v8.2 was used for the simulation. The DOE's reference prototype commercial buildings, which were developed by Pacific North National Laboratory (PNNL), were used for this study. These prototype commercial buildings were modified to make them compatible with the 2014 Florida Energy Code. The prototype commercial buildings, which had basement, were modified by removing the basement block. Computer simulation was run for the six Florida cities for each of the nine commercial buildings. The ERV credits were determined by comparing the energy uses of the proposed and the reference buildings. ERV devices were added to the prototype buildings where there is missing one. Also a brief description of the DOE commercial prototype buildings, changes made to the prototype buildings and the ERV device input assumptions.

2 Modeling Tool and Assumptions

A computer simulation analysis of ERV device energy savings potential was conducted using EnergyPlus, which is DOE's whole building energy simulation tool. EnergyPlus has component models that allow simulating both ERV and HRV devices. There are a few variations of design configurations for ERV devices placement in an air loop (Moffitt, 2014). The design configuration simulated for ERV credit is the most common configuration where the ERV is installed in the outdoor air system. A schematic of the HVAC system air loop with ERV placed in an outdoor air system is shown in Figure 1. A schematic representation of a central dedicated outdoor air system (DOAS) system with ERV is shown in Figure 2. The later configuration was used in large hotel prototype building serving guest rooms. The DOAS feeds the individual fan coil units serving guest rooms.

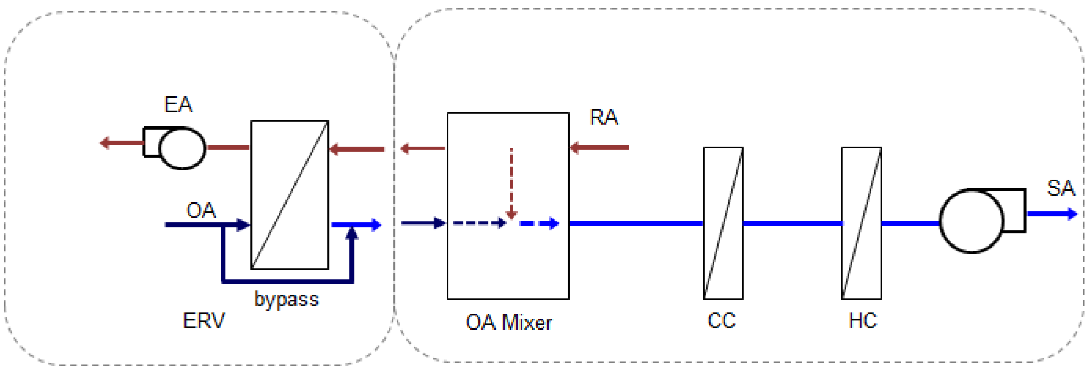

Figure 1 Schematics HVAC system with ERV and outdoor air mixer

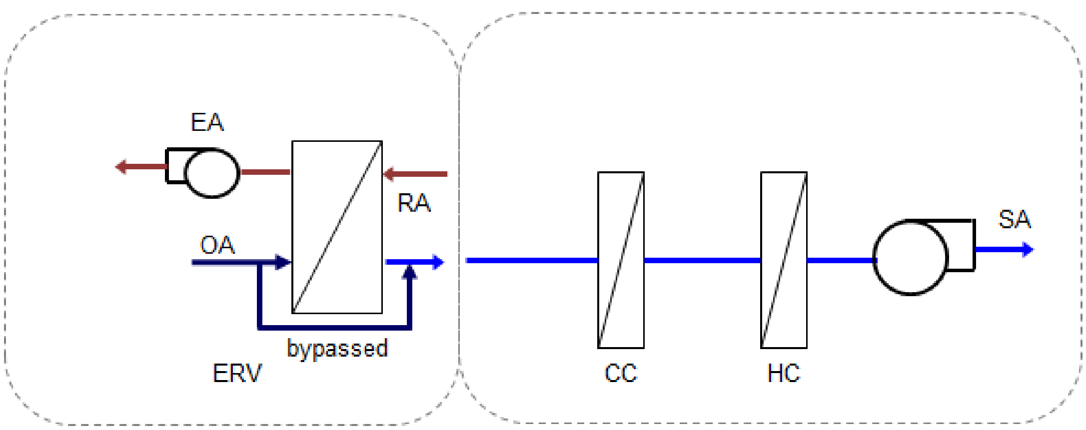

Figure 2 Schematics of a DOAS system with ERV

All the systems investigated in this study have Air Economizer except for Miami, which is climate zone 1. The Air Economizer and the Heat Recovery heat exchanger operation were controlled that whenever, the air economizer is active the heat recovery heat exchanger is set to off using a bypass. Also if there is any heating coil downstream of the outdoor air mixer and heating is required then the air economizer air flow rate is set to the minimum flow and the heat recovery device is turned on. When the heat recovery is on, the outdoor air flow rate is at minimum flow and the heating coils remains active.

In this study, the model assumptions refer to the inputs used in the ERV component model. The inputs to the ERV component model are the cooling and heating effectiveness at full and part–load operation, the auxiliary electric inputs and pressure drop across an ERV device. Heating and cooling effectiveness values were specified for sensible and latent heat transfer components. The EnergyPlus ERV component model object has input field used for specifying the auxiliary electric power required for control and motors driving the rotary wheel of ERV. For plate type heat exchangers the HRV auxiliary electric input were set to zero. The auxiliary electric power inputs of the ERV devices were obtained from manufacturers published catalogues and engineering judgement. The ERV sensible and latent effectiveness values for cooling and heating operation modes were also specified in the ERV object. The pressure drop across the ERV device for both supply and return air streams were specified in the supply and return fan objects, respectively. Pressure drop and effectiveness values used in this study were obtained from the AHRI Air-to-Air Energy Recovery Ventilators Directory of Certified Product Performance database (*http://www.ahrinet.org*). The type of ERV devices were selected based on sizing flow. The inputs assumption of the ERV devices used in this study are summarized in Table-A1 through Table-A9 in the Appendix.

The pressure drop due to ERV device was added to the supply and return air fan for all proposed building systems with ERV. However, the 2014 Florida Energy Code allows making fan total pressure adjustment for the reference building system supply and return air streams due to ERV device. It is thus, the energy savings potential, can be analyzed with and without fan pressure adjustment applied to the reference building system. Therefore, energy savings potentials were determined using two different reference building systems:

- The standard reference building system with no ERV device; and
- The standard reference building system with no ERV device but the pressure adjustment was applied to the supply and return fans per the 2014 Florida Energy Code.

Note that the proposed building systems used in both scenarios are identical. The proposed building system is modeled with ERV device added, i.e., the proposed building system is the standard reference building with ERV device added and pressure drop across the ERV device is accounted for. Two sets of energy savings analysis scenarios were performed:

Energy Savings Potential without Fan Pressure Adjustment: this energy savings is calculated by comparing the standard reference building without ERV device and the proposed building. The energy savings due to ERV device in discounted for the additional fan energy input.

Energy Savings Potential with Fan Pressure Adjustment: this energy savings is calculated by comparing the standard reference building without ERV and fan pressure adjustment applied, and the proposed building. In this scenario the additional pressure drop in the proposed building system is offset by the fan pressure drop adjustment applied to the reference building. Hence, energy savings is primarily due to ERV without accounting for the fan energy penalty.

It is therefore, higher energy savings potential is expected in the fan pressure adjusted scenario than that of without fan pressure adjusted. The ERV credits determined are based on the scenario that fan pressure adjustment were applied to the reference buildings. Instead of using the pressure drop adjustment values allowed by the 2014 Florida Code, we used the pressure drop of each ERV device selected from AHRI certified database. The actual pressure drop is always lower than the values allowed by the standard.

3 Prototype Commercial Buildings

Nine commercial prototype buildings were identified for computer simulation study of impacts of ERV devices on annual energy use. Summary of the prototype buildings including the conditioned floor area, the number of stories and the HVAC system types are provided in Table 1. Furthermore, a brief description of each of the nine buildings geometry, modifications made to the DOE's prototype buildings, the HVAC system, the design supply air and outdoor air flow rates are provided. The design supply air flow rates may slightly vary by city locations but Miami is used as a representative location for all buildings. A building may be served by multiple HVAC system types and ERV may not be added to all system types. Therefore, for each system types in a building the percentage of the total building conditioned served is also provided.

Table 1 Commercial prototype buildings summary

Reference Building	Floor Area ft^2 [m^2]	Number of Floors	Heating Type	Cooling Type	ASHRAE System Type
Large Office	460,236 [42,757]	12	HWFFB	CW	VAV
Medium Office	53,628 [4,982]	3	GF	DX	PVAV
Small Office	5,500 [511]	1	GF	DX	PSZ-AC
Large Hotel	100,816 [9,366]	6	HWFFB	CW	VAV
Large Hospital	201,250 [18,697]	5	HWFFB	CW	VAV
Small Hotel	40,097 [3,725]	4	GF + EF	DX	PTAC + PSZ-AC
Stand Alone Retail	24,962 [2,319]	1	GF	DX	PSZ-AC
Primary School	73,959 [6,871]	1	HWFFB	DX	PVAV + PSZ-AC
Secondary School	210,887 [19,592]	2	HWFFB	CW	VAV + PSZ-AC

For instance, the small hotel building is served by two HVAC system types: single zone constant volume packaged system with gas furnace serving the common areas such as office, meeting room, and front lounge, and packaged terminal air conditions (PTAC) serving the guest rooms, mechanical room and corridors. ERV device was added to the single zone systems serving the common areas but not to the PTACs serving the guest rooms. Therefore, the ERV added covered only the conditioned floor of the common area, which is only 12.7% of the total conditioned floor area. Thus, the annual HVAC energy savings of the common area of the small hotel buildings was normalized using the conditioned floor of the common areas only. A brief description of the modified nine commercial prototype buildings is provided here. For further detail of the reference prototype buildings refer to the PNNL report by *Thornton et al*. (2007).

Large Office Building

The DOE's reference prototype building for large office has 12 stories and a basement floor. The prototype large office was modified by removing the basement floor to make it compatible with the Florida Energy Code compliance requirement. The building total conditioned floor area is 42,757.3 m^2 (460,236 ft^2). The large office building HVAC system has central air VAV systems with reheat, outdoor air system, water cooled condenser, and fossil fuel heating type. A single central air VAV system serves each floor. And each floor was represented by four perimeter zones and a core zone. Each system has a central chilled water cooling coil, a hot water heating coil and terminal hot water reheat coils serving each zone. The ten middle floors were modeled using a zone multiplier and was represented by single VAV system. In total there are three VAV systems serving the bottom (first) floor, the ten middle floors and the top (last) floor. The prototype large office building input definition file (IDF) did not have an ERV device in the HVAC systems. Therefore, modifications were made to the HVAC systems by adding ERV device for each of the three central VAV systems. The ERV device coverage of the conditioned floor area was 100%. Summary of the input assumption of the ERV device are given in Table-A1. The ERV credit applies to the VAV system. System Type 2: VAV with Reheat. The large office building average design outdoor air flow fraction was 26.0%.

Table 2 Design air flow rates of large office building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
VAV With Reheat	99.0	244,083	64,533	26.0
CRAC	1.0	10,550	397	4.0

Medium Office Building

The DOE's reference prototype building for medium size office is a three story building. The total conditioned floor area of the building is 4,982 m^2 (53,628 ft^2). The office building has three central packaged VAV systems with terminal reheat that serves the bottom (first) floor, the middle floor and the top (last) floor of the building. And each floor has four perimeter zones and a core zone. Each packed VAV system has an outdoor air system, a variable speed DX cooling coil, a gas heating coil and terminal electric reheat coil serving each zone. The medium office building did not have an ERV device in the HVAC system. Therefore, modifications were made to the HVAC systems by adding an ERV device for each of the three packaged VAV systems. The ERV device coverage of the conditioned floor area was 100%. Summary of the inputs assumption of the ERV devices are provided in Table-A2. The ERV credit applies to the Packaged VAV system, which is System Type 4. The packaged VAV system does not use hot-water fossil fuel boiler, instead, it uses a gas heating coil and terminal electric reheat coils. The supply and outdoor air design flow rates of the building are provided in Table 3. The medium size office building average design outdoor air flow fraction was 23.0%.

Table 3 Design air flow rates of medium office building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
Packaged VAV	100.0	32,023	7,465	23.0

Small Office Building

The DOE's reference prototype building for small size office is a single story. The total conditioned floor area of the building is 500.0 m^2 (5382.0 ft^2). The building has four perimeter zones and a core zone. A packaged single speed air-to-air heat pump with gas supplemental heating coil serves each thermal zone. Each packaged heat pump has an outdoor air system. The prototype small office building input definition file (IDF) did not have an ERV device. Therefore, modifications were made to prototype reference building HVAC systems by adding ERV device for each of the single-zone packaged heat pumps. The ERV device coverage of the conditioned floor area was 100%. Summary of the inputs assumption of the ERV devices are provided in Table-A3. The ERV credit applies to the Packaged Roof top Heat Pump, System Type 9. This system uses gas supplemental heater. The supply and outdoor air design flow rates of the building are provided in Table 4. The small size office building average design outdoor air flow fraction was 14.0%. The outdoor air fraction of small office building is lower than that of the other office buildings.

Table 4 Design air flow rates of small office building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
PSZ-HP	100.0	3,446.1	467.6	14.0

Large Hospital Building

The DOE's reference prototype building for large hospital has five floors and a basement. Basement of the prototype large hospital building was removed to make it compatible with the Florida Energy Code requirement. The total conditioned floor area was 18,696.8 m^2 (201,250.2 ft^2). The building is served with seven central air VAV systems and each VAV system has an outdoor air system, electric humidifier, hot water heating coil, chilled water coil and terminal hot water reheat coils. The VAV systems serve the common service areas and corridors, operating rooms, emergency rooms, patient's rooms, emergency rooms, laboratories, and intensive care units. And a single zone constant volume HVAC system serves the kitchen. The prototype large hospital building did not have ERV devices. Thus, ERV devices were added to each of the seven VAV systems but not to system serving the kitchen. The ERV device coverage of the total conditioned floor area was 95.0%. Summary of the inputs assumption of the ERV device are given in Table-A7. The ERV credit applies to the VAV system with reheat, System Type 2. The supply and outdoor air design flow rates of the building are provided in Table 5. The large hospital building average design outdoor air flow fraction was about 58.5%.

Table 5 Design air flow rates of large hospital building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
VAV with Reheat	95.0	140,987	82,400	58.5

Large Hotel Building

The DOE's reference prototype building for large hotels has six floors and a basement. Basement block of the reference large hotel building was removed to make it compatible with the Florida Energy Code compliance requirement. The total conditioned floor area was 9,366 m^2 (100,815 ft^2). The large hotel building has two different HVAC system types: a central VAV system with reheat serving the common areas such as Lobby, Banquet, Dinning, Cafe, Retails, Corridors, Storage, kitchen and laundry, and dedicated outdoor air system and Fan Coil units serving the guest rooms. The central VAV system has a chilled water coil, a hot water heating coil, and terminal unit hot water reheat coils. The common areas conditioned floor size was 4,715 m^2 (50,752 ft^2), which is 50.3% of the total conditioned floor area. And the guest rooms conditioned floor area is 4,651 m^2 (50,063 ft^2). The outdoor air requirement of the guest rooms is provided by a constant volume DOAS. ERV device was added to the central VAV system and the constant volume DOAS. The ERV installation coverage was 100%. Summary of the inputs assumption of the ERV devices are given in Table-A4. The ERV credit applies to the VAV system with reheat and the constant volume DOAS that supplies outdoor air to the fan coil units. The supply and outdoor air design flow rates of the large hotel building are provided in Table 6. The large hotel building common area average design outdoor air flow fraction was 50.0%. And the average design outdoor air flow fraction of the guest rooms is 8.1%.

Table 6 Design air flow rates of large hotel building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
VAV with Reheat	50.3	38,569	19,403	50.0
DOAS – Fan Coil	49.7	49,104	4,346	8.9

Small Hotel Building

The DOE's reference prototype building for small hotels has four floors. The building total floor area is 4013.6 m^2 (43,202.0 ft^2) and the conditioned floor area is 3725.1 m^2 (40,096.6 ft^2). The guest rooms, corridors, and mechanical room rooms were conditioned using packaged terminal units (PTAC). The common areas: the front office, front lounge, meeting room and employee lounge rooms were conditioned using single zone constant volume packaged air conditioners and gas furnace system. The storage rooms, laundry, elevators, and stairs were not conditioned. The reference prototype building HVAC system did not have any ERV devices. Therefore, EVR device was added only to the single zone packaged HVAC systems serving the common. Thus, the ERV device coverage was only 12.7% of the total conditioned floor area. The packaged roof top air conditioners and gas furnace system type (System Type 11) covers the common area, and the packaged terminal air conditioners and electric heating coil system (System Type 10) covers the guest rooms. Summary of the inputs assumption of the ERV device are given in Table-A5. The annual HVAC EUI savings and the ERV credit apply to the Packaged Roof top Air Conditioner, which covers 12.7% of the total conditioned floor area of the buildings. The supply and outdoor air design flow rates of the small hotel building are provided in Table **7**. The small hotel building common area average design outdoor air flow fraction was 22.0%.

Table 7 Design air flow rates of small hotel building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
PSZ-AC	12.7	4,964	1,087	22.0
PTAC	87.3	-	-	-

Standalone Retail Building

The DOE's reference prototype building for standalone retail was a single story with four thermal zones. The total conditioned floor area of the retail building is 2,294 m^2 (24,692 ft^2). Each of the thermal zones in the standalone retail building was served with a packaged single zone constant volume system. Each packaged system has DX cooling coil and a gas heating coil. Plate heat exchanger ERV device was added to each of the four packaged single zone constant volume system. Summary of the inputs assumption of the ERV device are given in Table-A6. The ERV device installed covers the entire conditioned floor area. A constant volume packaged roof top air conditioners and gas furnace, *System Type 11* serves each zone. The ERV credit applies to the Packaged Roof top Air Conditioner. The supply and outdoor air design flow rates of the standalone retail building are provided in Table 8. The standalone retail building average design outdoor air flow fraction was 24.0%.

Table 8 Design air flow rates of standalone retail building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
PSZ-AC	100.0	22,153.5	5,250.6	24.0

Primary School Building

The DOE's reference prototype building for primary school was a single story with 6871.0 m^2 (73,958.8 ft^2) conditioned floor area. The Offices, Class Rooms, Lobby, and Main Corridor are served with Packaged VAV system with reheat. Each of the packaged VAV system has a variable speed DX cooling coil, a hot water heating coil, and a hot water reheat coil serving each zone in an air loop. The cafeteria, gymnasium and kitchen are served with constant volume single zone packaged system with gas heating coils. The ERV device coverage of the conditioned floor area is 97.6%. The kitchen does not have an ERV device. Summary of the input assumptions of the ERV device are given in Table-A8. The packaged VAV system with reheat, which is *System Type 4, c*overs 87.8% of the conditioned floor area. The constant volume packaged roof top air conditioners and gas heating coil, which is S*ystem Type 11, c*overs 9.8% of the total conditioned floor area. The supply and outdoor air design flow rates of the primary school building are provided in Table 9. The primary school building average design outdoor air flow fraction was 85.1%.

Table 9 Design air flow rates of primary school building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
VAV DX with Reheat	87.8	31,554.3	26,850.4	85.1
CAV Packaged DX	9.8	5,053.0	4,305.8	85.2

Secondary School Building

The DOE's reference building for secondary school was a two story with all conditioned space. The building total conditioned floor area was 19,592 m^2 (210,887 ft^2). The class rooms, which are 35.3% of the total conditioned floor area, offices, mechanical rooms, lobby, main corridor, library and media rooms were served with four central air VAV systems with chilled water coil, hot water coils, and hot water terminal reheat coil. The cafeteria, gymnasium, auditorium, and kitchen each served with single zone constant volume packaged system with gas heating coil. The four VAV systems and the single zone constant volume packaged systems serving the gymnasium, cafeteria, and auditorium had ERV device. The secondary school building did not have ERV for the kitchen. The conditioned floor area covered by the ERV device was 98.9%. Summary of the inputs assumption of the ERV device are given in Table-A9. The central VAV system with reheat, which is *System Type 4, c*overs 74.2% of the total conditioned floor area. The constant volume packaged roof top air conditioners and gas heating coil, which is S*ystem Type 11*, covers 24.7% of the total conditioned floor area. The supply and outdoor air design flow rates of the secondary school building are provided in Table 10. The secondary school building average design outdoor air flow fraction was 75.0%.

Table 10 Design air flow rates of secondary school building by system type

System Type	Floor Area, %	Design Flow Rate, cfm	OA Design Flow Rate, cfm	Fraction of OA Design Flow Rate, %
VAV With Reheat	74.2	93,948.4	71,795.3	78.0
CAV Packaged DX	24.7	36,593.8	25,269.9	69.0

4 Energy Savings Analysis and Results

Nine commercial buildings in six Florida cities were simulated to determine the energy savings potential of ERV devices. These cities were: Miami, Tampa, Orlando, Jacksonville, Gainesville, and Tallahassee. Miami is in climate zone 1A, and the rest are in climate zone 2A. The nine commercial buildings investigated were the prototype reference buildings originally developed by PNNL. Modifications were made to the reference buildings geometry by removing the basement block to make them compatible with Florida Energy Code requirement. The energy use and savings metrics were determined for the building with and without the ERV device installed. The building energy uses without ERV device were used as the reference. The energy use or energy savings were reported as intensities by normalizing them using the conditioned floor area of the buildings. The ERV device energy savings in percent were calculated by dividing the HVAC total energy savings by the reference building HVAC total energy use. The HVAC energy savings may vary by building type, weather locations, and HVAC system type. Moreover, the following parameters and ERV device inputs assumption may impact the annual HVAC energy savings potential:

- Building operating hours per day: building operating hours is one parameter that varies by building type and impacts the energy savings due to ERV device; some building types such as office and schools may operate for about 12 hours a day when the outdoor air temperature is near the daily high, whereas some buildings such as hotels and hospitals operate 24 hours every day and others such as retail buildings operate for about 16 hours a day. In addition, offices and school buildings are off during weekends. Building types such as schools and office that operate during extreme outdoor air temperature hours may show higher percent energy savings potential compared to the buildings that operate during less-severe outdoor air temperature hours. In general schools are expected to save higher energy compared to the office buildings due to higher outdoor air fraction.
- Outdoor air flow fraction relative to the design supply air flow. *Christman et al.*, (2009) study demonstrated using office and laboratory building in Texas, USA, that higher outdoor air fraction increase the energy savings potential of ERV device.
- Part-load performance of HVAC Systems. HVAC system type also impacts the ERV energy savings potential. HVAC system types that have efficient part load performance may gain more energy savings than those with less or no part load efficiency gain. In general VAV systems have higher potential of energy savings due to ERV installation. VAV systems with chilled water and hot water loops are expected to show higher annual energy savings compared to VAV DX systems due to higher part-load efficiency.
- Constant versus Variable Flow Fan: constant flow fan introduces higher fan energy use due to ERV device installation compared variable flow fan. Hence, the energy savings due to ERV is lower compared to the VAV system.
- Impacts of the ERV device inputs assumption: the cooling and heating effectiveness, ERV pressure drop, and auxiliary electric power inputs assumptions. Impacts of these inputs assumption are discussed in Section 6.

Figure 3 shows the annual HVAC energy use intensity (EUI) savings by building type and cities for the nine commercial buildings investigated using the standard reference building without fan pressure adjustment due to ERV applied and the proposed building with ERV. The annual HVAC EUI savings are the difference between the EUI of a building without and with ERV device installed. Pressure drops due to ERV devices were applied to the proposed buildings.

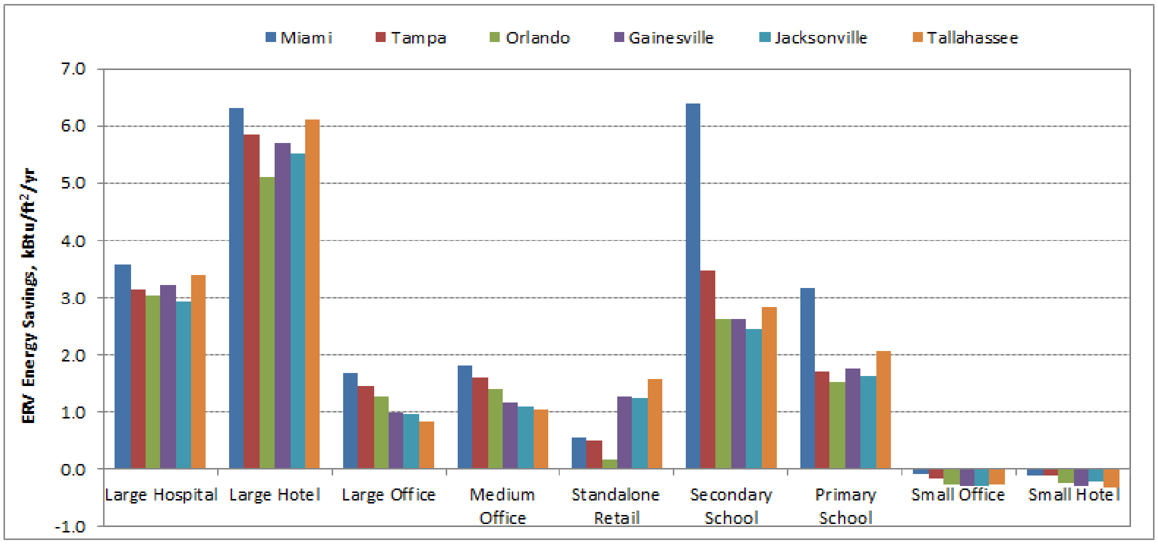

Figure 3 Annual HVAC EUI savings without fan pressure adjustment applied

Figure 4 shows the annual HVAC energy use intensity (EUI) savings by building type and cities for the nine commercial buildings using the modified standard reference building and the proposed building. The modified reference building is the standard reference building with fan pressure adjustment applied due to ERV per the 2014 Florida Energy Code. The annual HVAC EUI savings are slightly higher than that determined without adjusting the supply and return fan total pressures.

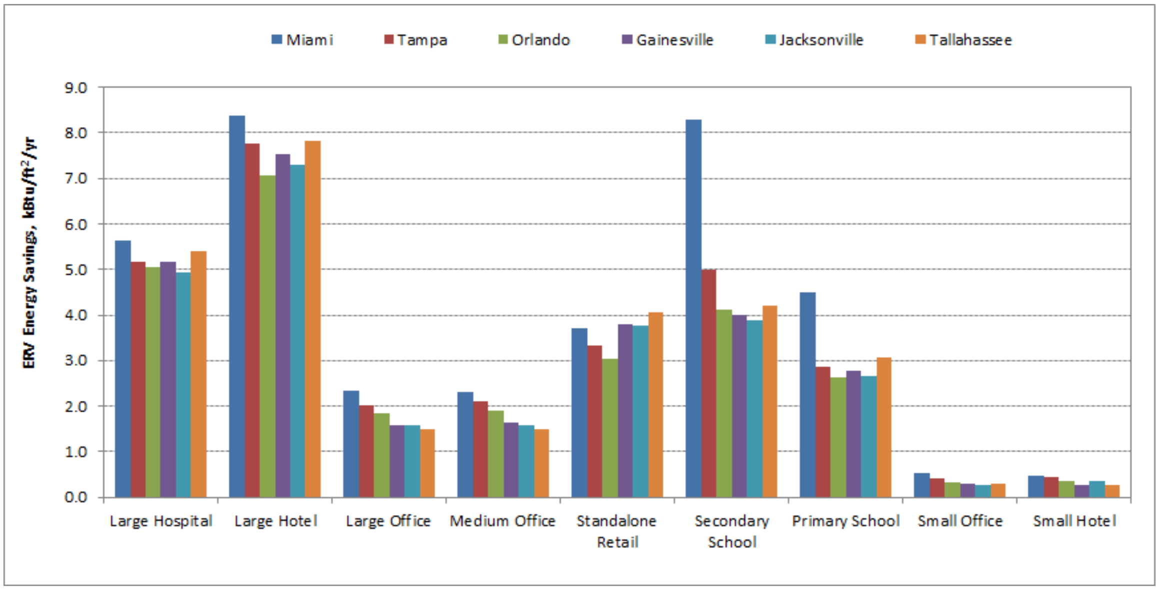

Figure 4 Annual HVAC EUI savings with fan pressure adjustment applied

The following sections describe the energy savings potential of buildings without and with fan adjustment applied scenarios. The HVAC energy savings potential are presented by building type and cities.

4.1 Performance without Fan Pressure Adjustment

This sub-section presents the energy savings potential of an ERV device installed without fan pressure adjustment applied to the reference building. In other words, the pressure drop due to ERV device is added to the proposed building and the reference building is modeled without ERV and no fan pressure adjustment was applied even though such fan total pressure adjustment is allowed per the 2014 Florida Energy Code. The HVAC annual energy savings without fan pressure adjustment shows the minimum possible. In this scenario, the annual HVAC energy savings is reduced by the fan energy penalty incurred due to pressure drop in the ERV device. Figure 5 through Figure 13 show the annual HVAC EUI for the reference and proposed buildings. Summary of annual HVAC EUI savings (kBtu/hr/ft^2/yr) by building type and cities is shown in Table 11.

The small office and small hotel buildings do not save annual HVAC energy as shown in Figure 12 and Figure 13. This implies the fan energy used by the ERV to overcome the additional pressure drop in the proposed building more than offsets the energy recovered by the HRV device. Note that a plate type HRV device was selected for the small office and small hotel buildings and the auxiliary electric power input to the HRV devices was set to zero for all systems in these two buildings. One explanation for no net energy savings is that the pressure drop for HRV in these two buildings is higher relative to the design air flow rates. Moreover, for a constant volume system a fixed fan energy penalty is applied so long as the system is on.

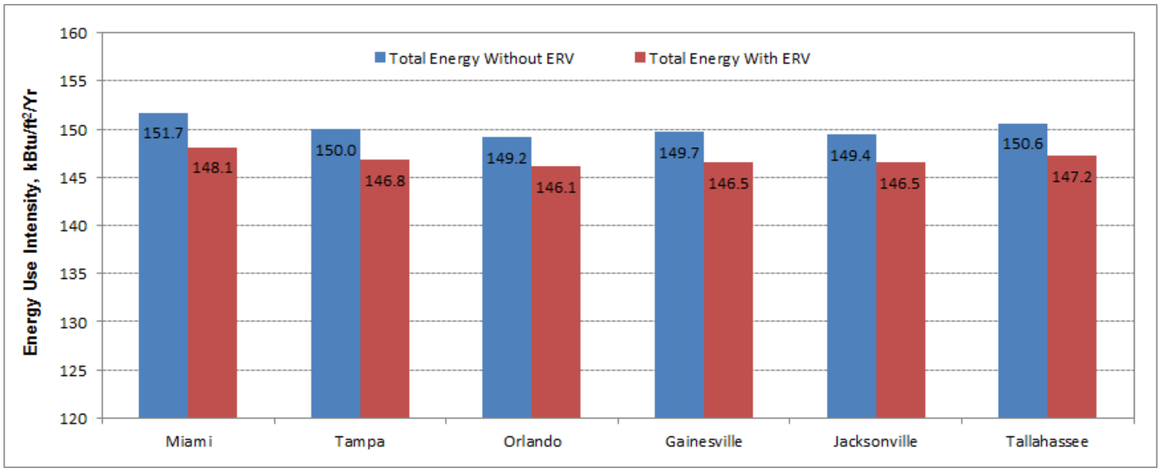

Figure 5 Annual HVAC EUI in a large hospital building without fan pressure adjustment

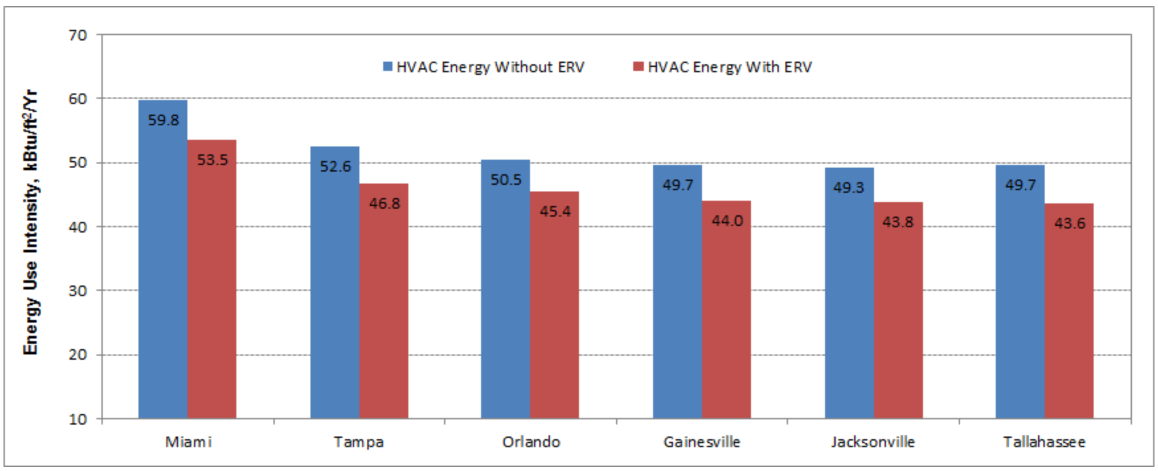

Figure 6 Annual HVAC EUI in a large hotel building without fan pressure adjustment

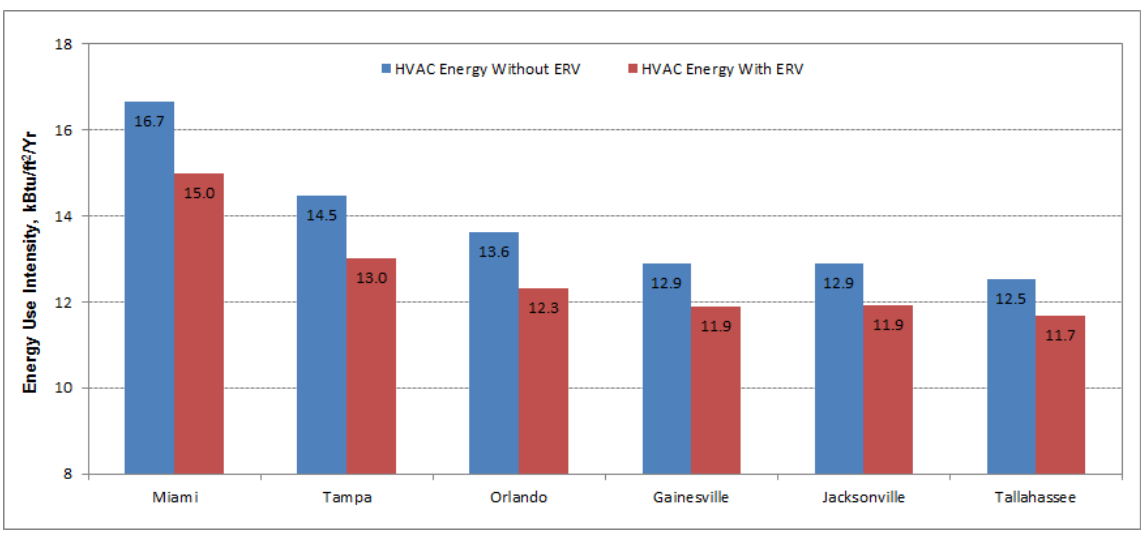

Figure 7 Annual HVAC EUI in a large office building without fan pressure adjustment

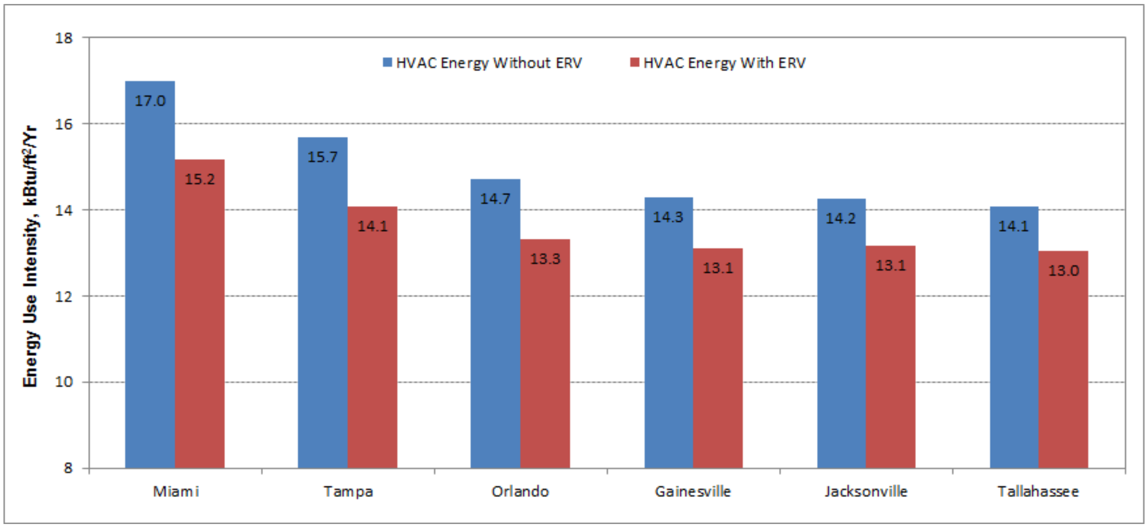

Figure 8 Annual HVAC EUI in a medium office building without fan pressure adjustment

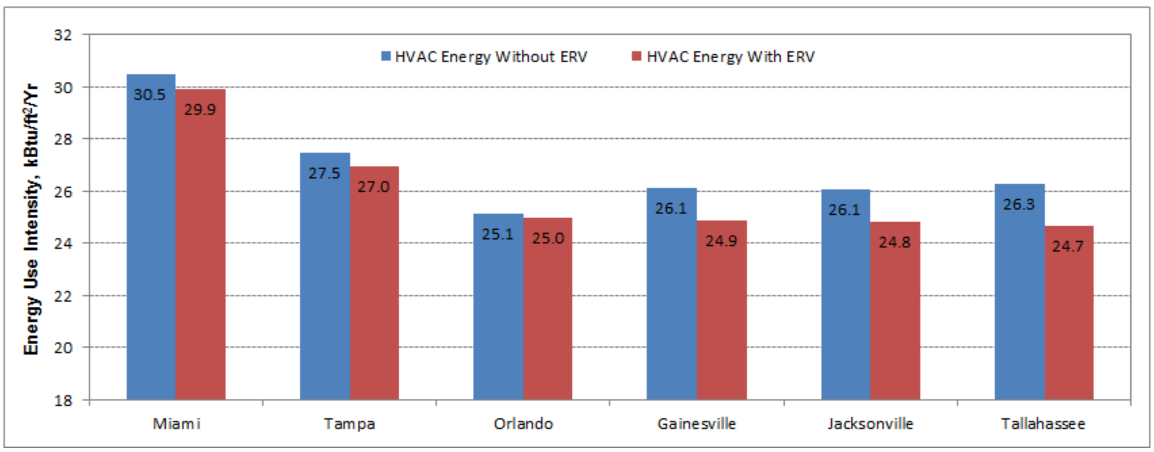

Figure 9 Annual HVAC EUI in a standalone retail building without fan pressure adjustment

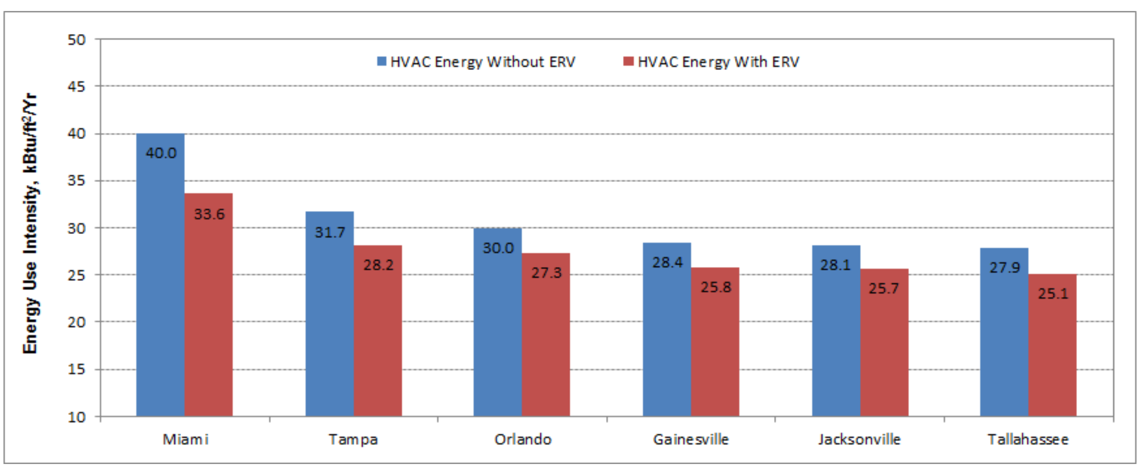

Figure 10 Annual HVAC EUI in a secondary school building without fan pressure adjustment

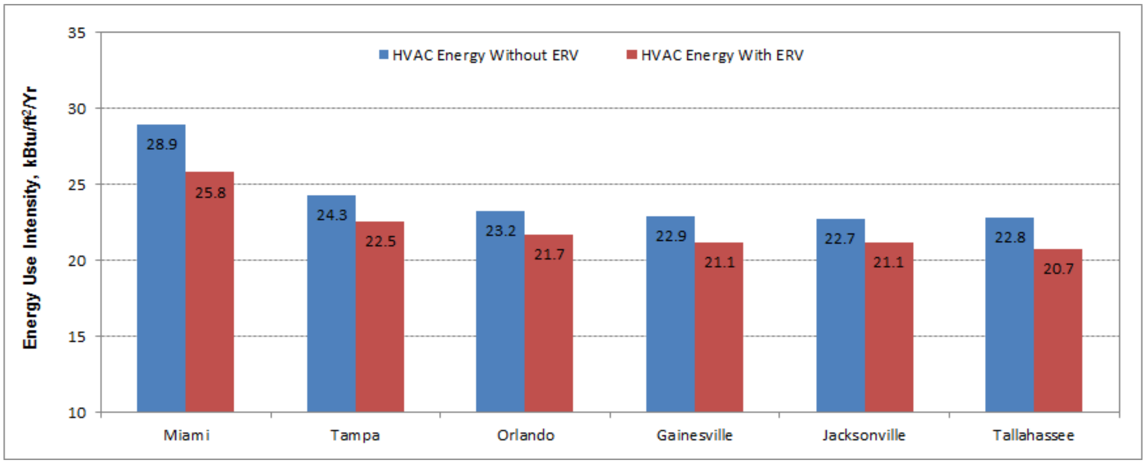

Figure 11 Annual HVAC EUI in a primary school building without fan pressure adjustment

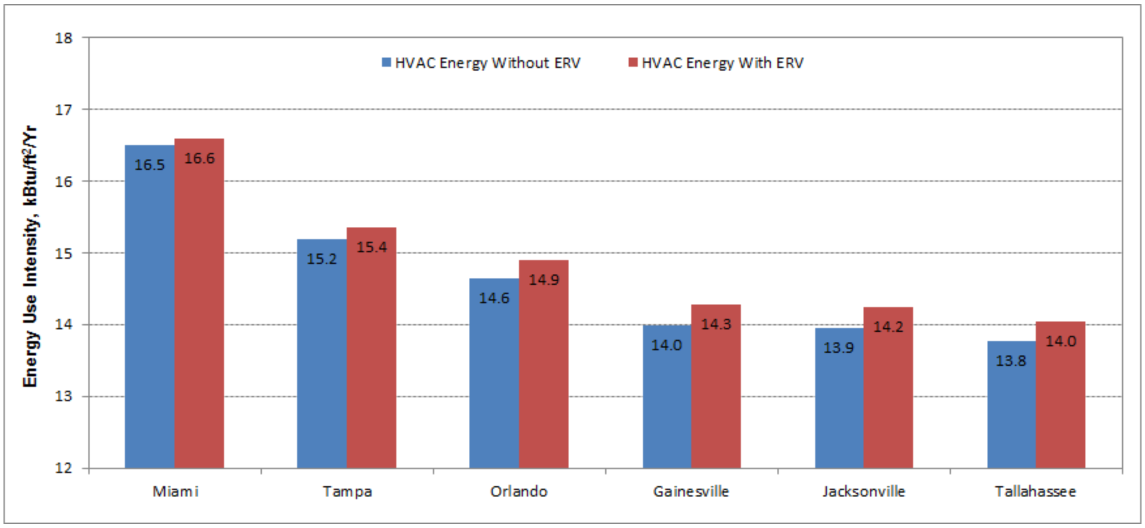

Figure 12 Annual HVAC EUI in a small office building without fan pressure adjustment

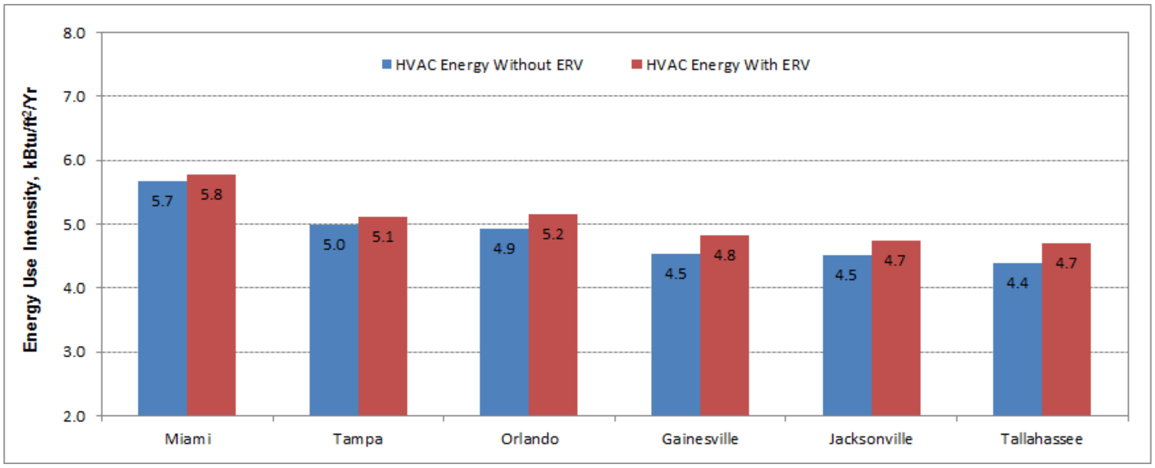

Figure 13 Annual HVAC EUI in a small hotel building without fan pressure adjustment

The following section summarizes the annual HVAC EUI savings of the nine commercial buildings by building type and cities. The HVAC EUI savings include the cooling, heating and fan energy uses of a building. Table 12 summarized the annual HVAC energy savings in percent for scenario without fan pressure adjustment applied to the reference building. The small office and small hotel buildings do not show any annual HVAC energy savings primarily due to high fan energy penalty of the ERV device.

Table 11 Annual HVAC EUI savings without fan pressure adjustment

Cities	Large Hospital	Large Hotel	Large Office	Medium Office	Standalone Retail	Secondary School	Primary School	Small Office	Small Hotel
Miami	3.58	6.30	1.67	1.81	0.56	6.39	3.16	-0.09	-0.12
Tampa	3.15	5.84	1.44	1.60	0.52	3.46	1.72	-0.16	-0.11
Orlando	3.04	5.11	1.28	1.40	0.18	2.64	1.53	-0.26	-0.23
Gainesville	3.21	5.71	1.00	1.18	1.27	2.62	1.77	-0.28	-0.29
Jacksonville	2.94	5.52	0.96	1.10	1.25	2.46	1.62	-0.30	-0.22
Tallahassee	3.40	6.11	0.85	1.04	1.58	2.84	2.06	-0.27	-0.31

Table 12 Annual HVAC energy percent savings without fan pressure adjustment

Cities	Large Hospital	Large Hotel	Large Office	Medium Office	Standalone Retail	Secondary School	Primary School	Small Office	Small Hotel
Miami	4.74	10.53	10.03	10.68	1.83	15.99	10.91	-0.55	-2.06
Tampa	4.27	11.10	9.96	10.20	1.87	10.93	7.08	-1.07	-2.24
Orlando	4.18	10.12	9.42	9.52	0.71	8.80	6.57	-1.74	-4.59
Gainesville	4.39	11.49	7.79	8.22	4.85	9.22	7.73	-2.01	-6.39
Jacksonville	4.04	11.21	7.47	7.69	4.78	8.74	7.12	-2.13	-4.89
Tallahassee	4.59	12.29	6.79	7.37	6.03	10.17	9.06	-1.98	-6.98

4.2 Performance with Fan Pressure Adjustment

This sub-section presents the energy savings potential of an ERV device installed and fan pressure drop adjustment applied to the reference building system. In other words, the pressure drop due to ERV device installed is added not only to the proposed building and but also to the reference building system as well. The reference and proposed buildings HVAC system are modeled with the same external pressure for the supply and return fans but ERV device is added to the proposed building system. As the result, the pressure drop adjustment applied to the reference building washout the impacts of the additional pressure drop due to the ERV device added in the proposed building system. Therefore, it can be said that this scenario represents the maximum HVAC energy savings potential that can be realized by an ERV device. The fan pressure adjustment is allowed by the 2014 Florida Energy Code.

Large Hospital Building Result

Figure 14 shows the large hospital building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 95.0%. The average ratio of design outdoor air flow rate to the design supply air flow rate for large hospital was about 58.5%. The annual HVAC EUI savings predicted range was 4.94 – 5.63kBtu/ft^2/yr. The highest savings was observed in Miami. Hospitals operate 24 hours a day; however, sometimes in mild outdoor air temperature hours in particular during the night, the condition may not be favorable for ERV device to turn on. Thus, during those mild outdoor air conditions the ERV could be off. The *Operating Room*, *Emergency Room*, and *Intensive Care Unit* of the large hospital building are served with 100% outdoor air system; hence, the fan energy penalty due to ERV can be significant.

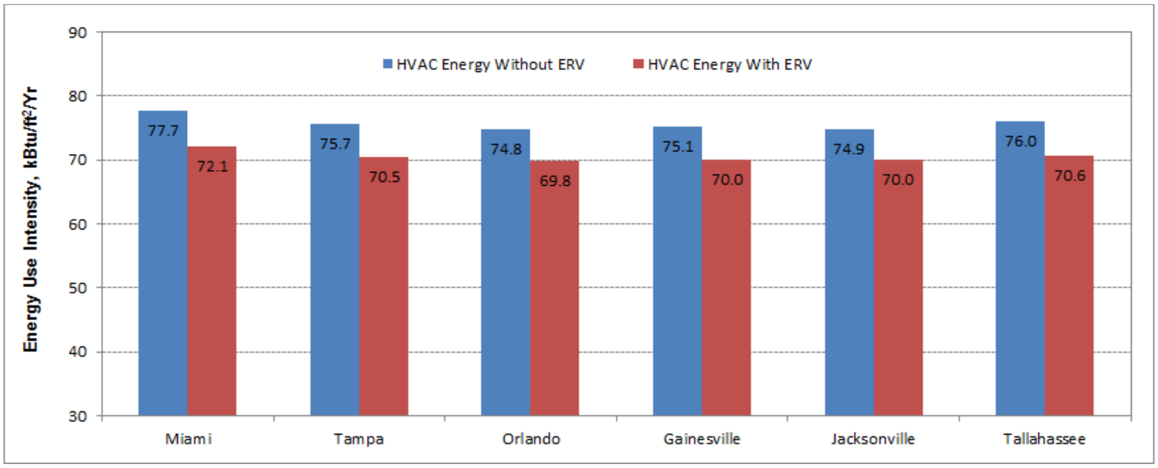

Figure 14 Annual HVAC EUI in a large hospital building with fan pressure adjustment

Large Hotel Building Result

Figure 15 shows the large hotel building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 100.0%. The HVAC system serving the guest rooms has a central dedicated outdoor air system (DOAS) that feeds outdoor air to the fan coil units of the guest rooms. The outdoor air is pretreated in the ERV unit, which is part of the DOAS. Since the outdoor air flow through the ERV of the DOAS was constant, fixed additional fan energy due to ERV device was applied to the supply and exhaust air side of the DOAS system. The average ratio of design outdoor air flow rate to the design supply air flow rate for large hotel building was about 55.0%. The annual HVAC EUI savings range was 7.06 - 8.39kBtu/ft^2/yr. The highest energy savings was observed in Miami.

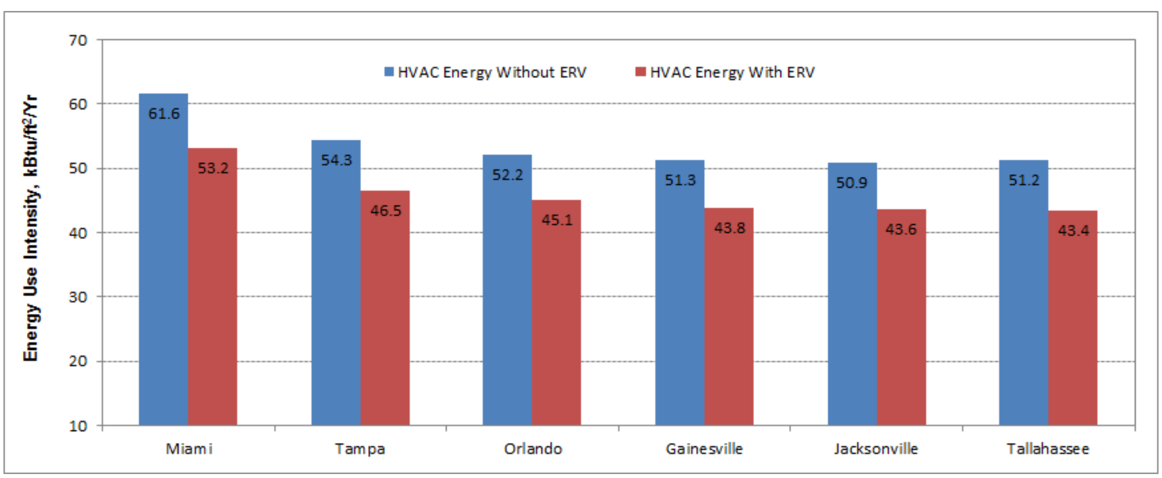

Figure 15 Annual HVAC EUI in a large hotel building with fan pressure adjustment

Large Office Building Result

Figure 16 shows the large office building annual HVAC EUI with and without ERV device installed. The ERV coverage of the total conditioned floor area was 100.0%. The average ratio of the outdoor air design flow rate to design supply air flow rate for large office building was 26.0%. Each floor is served with a central VAV with chilled water cooling coils, hot water heating coils and terminal hot water reheat coils. The ten middle floors were represented by single central system using zone multipliers. The annual HVAC EUI savings range was 1.48 - 2.33kBtu/ft^2/yr.

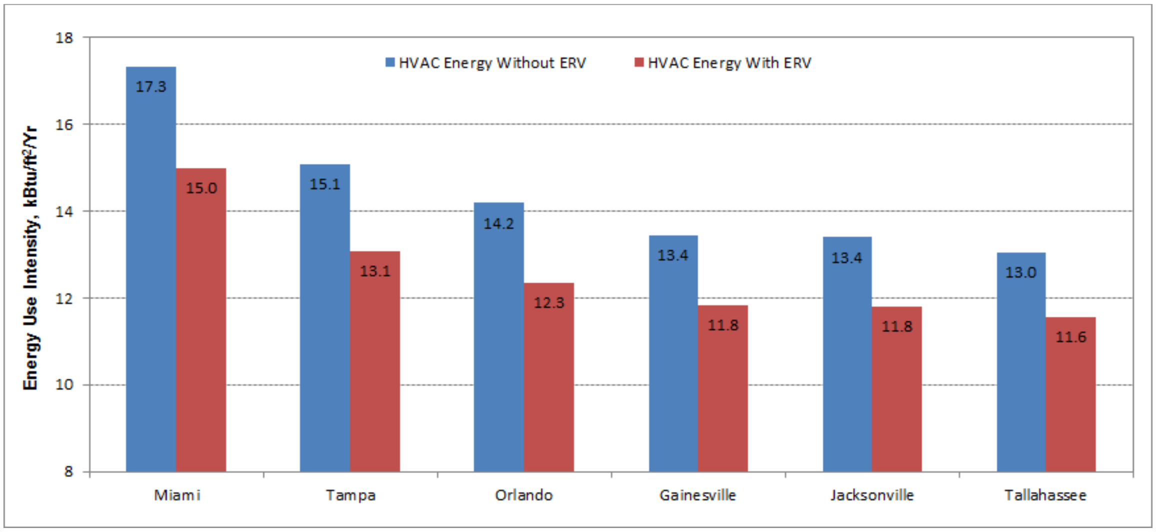

Figure 16 Annual HVAC EUI in a large office building with fan pressure adjustment

Medium Office Building Result

Figure 17 shows the medium office building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 100.0%. Each of three floors was served with a central packaged VAV with DX cooling coils, a gas heating coil and terminal electric reheat coils. The average ratio of the outdoor air design flow rate to design supply air flow rate for medium office building was 23.0%. The annual HVAC EUI savings range was 1.51 - 2.32kBtu/ft^2/yr. The large and medium size office buildings show a similar annual HVAC EUI and percent savings. The small differences observed are due to two main factors: difference in ERV average effectiveness, 72% for medium office and 68% for large office building systems. The second factor is lower part load performance of the VAV DX system in medium office building compared to Chilled and Hot water VAV system in the large office building. Thus, slightly higher effectiveness impact of the medium office building ERV device was offset by lower part-load performance of its VAV DX system.

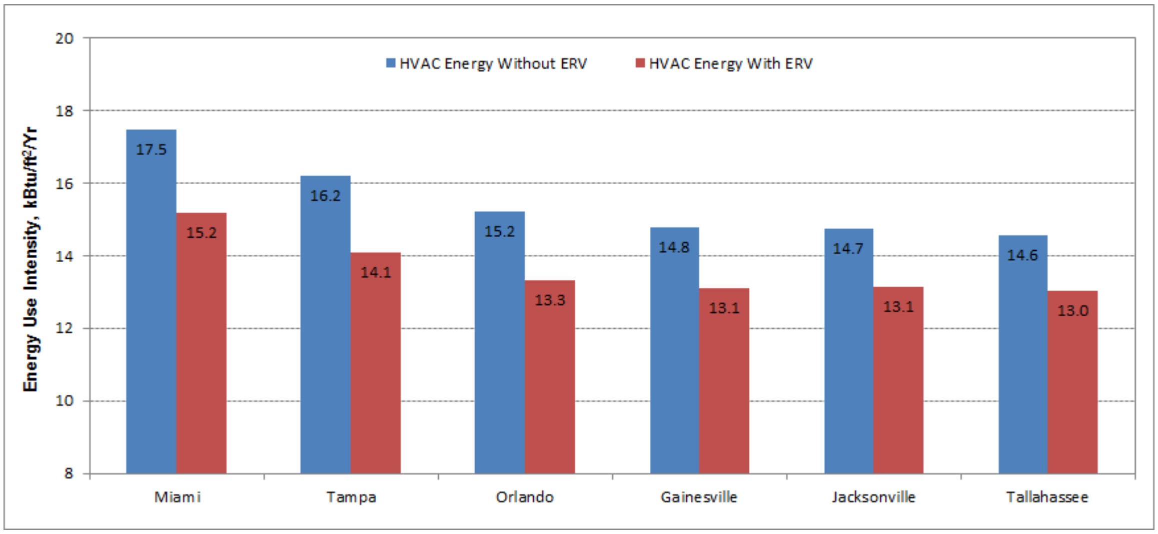

Figure 17 Annual HVAC EUI in a medium office building with fan pressure adjustment

Standalone Retail Building Result

Figure 18 shows the standalone retail building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 100.0%. The average ratio of the outdoor air design flow rate to design supply air flow rate for standalone retail building was 24.0%. A constant volume packaged system with DX cooling coil and a gas heating coil serve each of the four thermal zones. The annual HVAC EUI savings range was 3.03 - 4.05kBtu/ft^2/yr. The retail building has almost the same outdoor air fraction, but has longer hours of operation per day and higher plug loads compared to the office buildings. However, the annual HVAC energy percent savings are approximately 1.0 - 2.0% lower than that of the office buildings. There are a number of factors that explain the savings difference including: difference in constant volume versus variable air volume systems, operating hours per day, efficiencies of the cooling and heating equipment, and difference in fraction of load due to outdoor air.

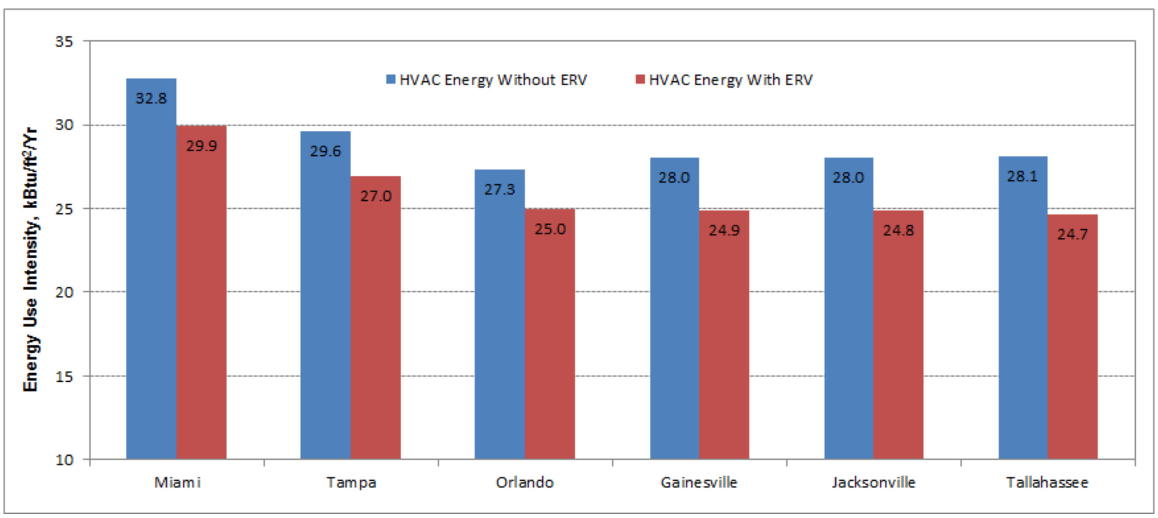

Figure 18 Annual HVAC EUI in a standalone retail building with fan pressure adjustment

Primary School Building Result

Figure 19 shows the primary school building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 100.0%. The average ratio of the outdoor air design flow rate to design supply air flow rate for primary school building was 85.0%. The annual HVAC EUI savings range was 2.62 - 4.51kBtu/ft^2/yr. The primary school building is a single story and 87.8% of the conditioned floor area is covered by a VAV DX system.

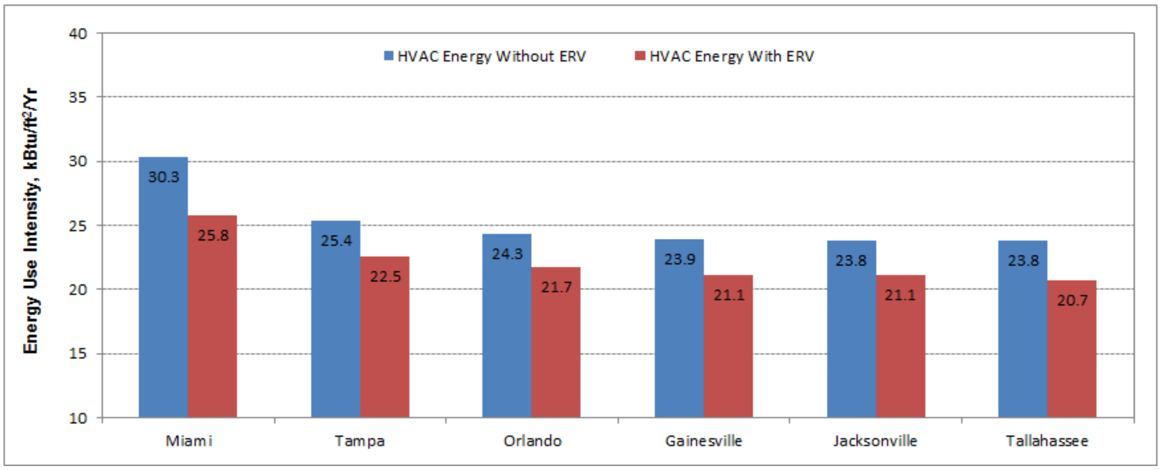

Figure 19 Annual HVAC EUI in a primary school building with fan pressure adjustment

Secondary School Building Result

Figure 20 shows the secondary school building annual HVAC EUI with and without ERV device installed. The ERV device coverage of the total conditioned floor area was 100.0%. The average ratio of the outdoor air design flow rate to design supply air flow rate for secondary school building was 75.0%. The annual HVAC EUI savings range was 3.87 - 8.28kBtu/ft^2/yr. The secondary school building is a two story and 72.4% of the conditioned floor area is served by VAV chilled water with hot water heating and reheat coils systems. Fraction of outdoor air contribution to the system load is lower for secondary school compared to that of the primary school due to number of story difference. Moreover, the part-load energy savings of VAV chilled system is expected to be better than VAV DX system. Thus, slightly higher annual HVAC EUI savings is expected in secondary school than that of the primary school design.

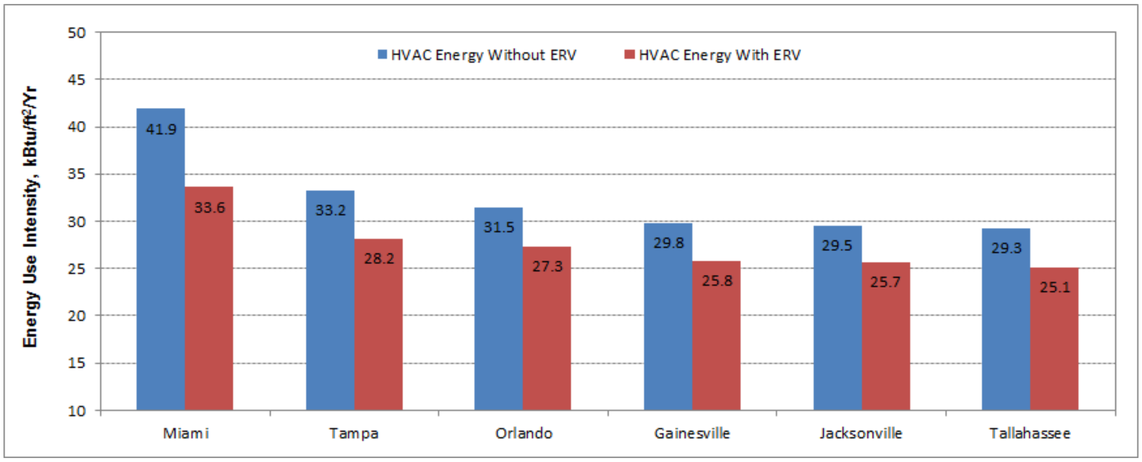

Figure 20 Annual HVAC EUI in a secondary school building with fan pressure adjustment

Small Office Building Result

Figure 21 shows the small office building annual HVAC EUI with and without ERV installed. The ERV coverage of the total conditioned floor area was 100.0%. The small office building average ratio of the outdoor air design flow rate to design supply air flow rate was 14.0%. The annual HVAC EUI savings range was 0.27 – 0.53kBtu/ft^2/yr. The lower energy savings of ERV device in small office building is attributed to: small outdoor air fraction, lower effectiveness due to small sized, smaller fans fan and motor efficiency, low minimum outdoor air flow rate, and constant speed DX systems do not have part load efficiency benefits.

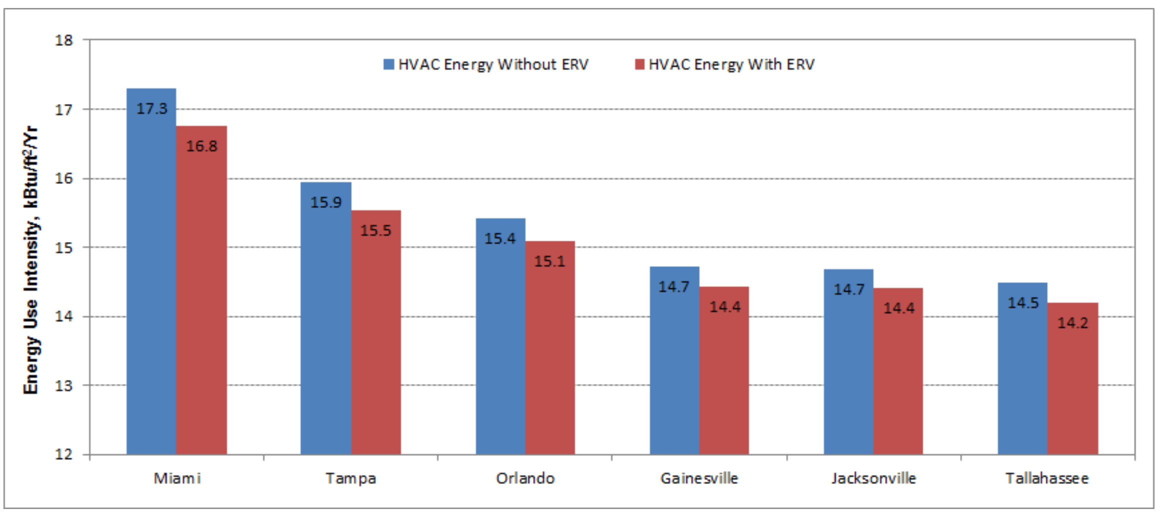

Figure 21 Annual HVAC EUI in a small office building with fan pressure adjustment

Small Hotel Building Result

Figure 22 shows the small hotel building annual HVAC EUI with and without ERV installed. The ERV coverage of the total conditioned floor area is 12.7% and the other 87.3% of the conditioned floor area is covered by guest rooms and the later does not have ERV devices installed. The average ratio of the outdoor air design flow rate to design supply air flow rate for small hotel building section where ERV installed was 22.0%. The annual cooling and heating

HVAC EUI savings range was 0.26 – 0.47kBtu/ft^2/yr. The annual savings was normalized using the total conditioned floor area of the common area only.

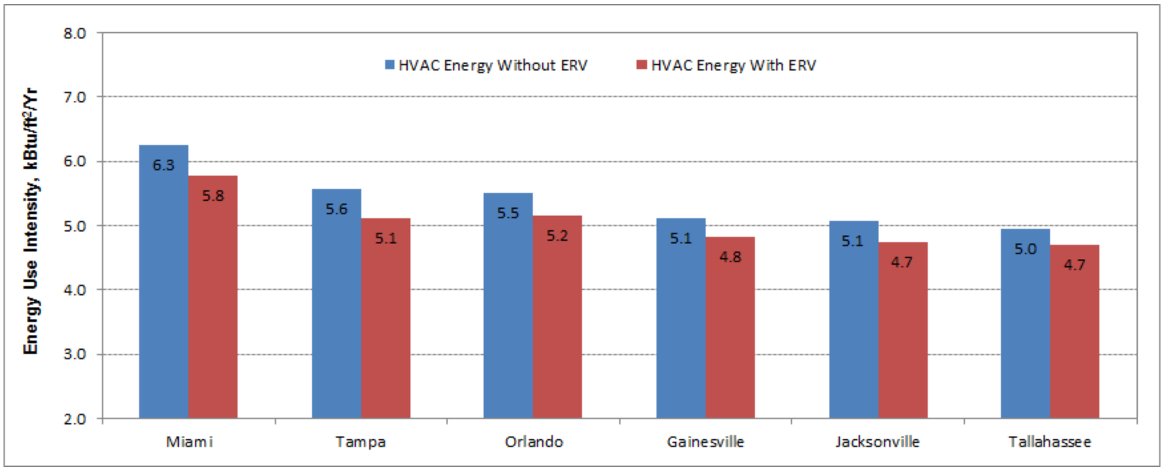

Figure 22 Annual HVAC EUI in a small hotel building with fan pressure adjustment

The annual HVAC EUI (kBtu/hr/ft^2/yr) savings and annual HVAC percent savings due to ERV device installation and fan pressure adjustment applied to the reference building system are summarized by building type and cities in Table 13 and Table 14, respectively.

Table 13 Annual HVAC EUI savings due to ERV device installation

Cities	Large Hospital	Large Hotel	Large Office	Medium Office	Standalone Retail	Secondary School	Primary School	Small Office	Small Hotel
Miami	5.63	8.39	2.33	2.32	3.70	8.28	4.51	0.53	0.47
Tampa	5.16	7.78	2.00	2.11	3.34	4.98	2.86	0.41	0.45
Orlando	5.05	7.06	1.84	1.89	3.03	4.13	2.62	0.33	0.36
Gainesville	5.18	7.52	1.59	1.65	3.79	4.01	2.78	0.28	0.28
Jacksonville	4.94	7.31	1.59	1.58	3.76	3.87	2.66	0.27	0.34
Tallahassee	5.40	7.84	1.48	1.51	4.05	4.20	3.06	0.29	0.26

Table 14 Annual HVAC percent savings due to ERV device installation

Cities	Large Hospital	Large Hotel	Large Office	Medium Office	Standalone Retail	Secondary School	Primary School	Small Office	Small Hotel
Miami	7.24	13.62	13.45	13.28	11.01	19.78	14.88	3.09	7.50
Tampa	6.82	14.32	13.30	13.05	11.03	15.02	11.25	2.59	8.13
Orlando	6.76	13.53	12.96	12.41	10.83	13.11	10.78	2.17	6.49
Gainesville	6.89	14.67	11.85	11.18	13.22	13.45	11.63	1.92	5.41
Jacksonville	6.59	14.38	11.88	10.72	13.16	13.12	11.16	1.81	6.70
Tallahassee	7.11	15.29	11.37	10.35	14.09	14.35	12.86	1.98	5.20

5 Developing ERV Credits

Some of commonly used code compliance software do not have ERV modeling capabilities but may predict annual Energy use of a standard reference building without ERV. ERV credits allow determining the energy savings of an ERV device without modeling the ERV device. This approach requires pre-determined ERV credits for code compliance practitioners to determine the energy savings due to ERV device installation. This study is intended to determine the ERV credits for variety of buildings and climate zones in the state of Florida. ERV credit is defined as the aggregate annual HVAC energy savings as percentage of the annual HVAC energy uses of a standard reference building. The annual HVAC energy use is the energy used for cooling, heating, and fans energy uses of a standard reference building. This section describes determination and application of ERV credits for code compliance calculation.

5.1 Determination of ERV Credits

The ERV credits for a building is determined from the annual HVAC energy use of a standard reference building with and without ERV device installed. The annual HVAC energy use is the annual heating, cooling and fan energy uses of a building predicted using whole building energy simulation tool. The heating and cooling energy includes the electric and gas energy use for heating and cooling a building and the fan energy includes the energy uses of supply and return air fans. The annual percent HVAC energy savings due to ERV device installation is given by:

$$ERVCredit = 100\frac{E_{woERV} - E_{wERV}}{E_{woERV}} \qquad 1$$

Where,

$ERVCredit$ = annual HVAC energy savings, %

E_{woERV} = annual HVAC energy use without an ERV device installed, Btu (Joule).

E_{wERV} = annual HVAC energy use with an ERV device installed, Btu (Joule).

The ERV credits for each of the nine commercial buildings by cities were determined using computer simulation and are summarized in Table 15. The ERV credits vary by building application type, weather (cities), daily and weekly operating schedule, inputs assumption of the ERV device, and HVAC system type. The building operating hours per day also varies by building application. Also the HVAC system type varies with building application type. The smaller buildings commonly use constant volume HVAC systems, which is prone to less or no annual HVAC energy savings due to ERV device, primarily due to higher fan energy penalty and poor part-load performance.

Table 15 ERV credits by building type and cities

Cities	Large Hospital	Large Hotel	Large Office	Medium Office	Standalone Retail	Secondary School	Primary School	Small Office	Small Hotel
Miami	7.24	13.62	13.45	13.28	11.01	19.78	14.88	3.09	7.50
Tampa	6.82	14.32	13.30	13.05	11.03	15.02	11.25	2.59	8.13
Orlando	6.76	13.53	12.96	12.41	10.83	13.11	10.78	2.17	6.49
Gainesville	6.89	14.67	11.85	11.18	13.22	13.45	11.63	1.92	5.41
Jacksonville	6.59	14.38	11.88	10.72	13.16	13.12	11.16	1.81	6.70
Tallahassee	7.11	15.29	11.37	10.35	14.09	14.35	12.86	1.98	5.20

5.2 Application of ERV Credits

In code compliance calculation the ERV credit is used to estimate the annual HVAC energy savings due to the ERV device installation. The HVAC energy savings are determined by multiplying the annual HVAC energy use of the standard reference building with the appropriate ERV credit. Thus, the code compliance calculation needs to simulate the building system without ERV and use pre-determined appropriate ERV credit to estimate the annual HVAC energy savings due to the ERV device installation. Mathematical representation of the energy savings calculation for code compliance calculation is formulated by rearranging equation-1and is given by:

$$\Delta E_{savings} = \frac{ERVCredit}{100} \cdot E_{woERV} \qquad 2$$

Where,

E_{woERV} = annual HVAC energy use without an ERV device installed, Btu (Joule)

$ERVCredit$ = ERV credit, %

6 ERV Credit Sensitivity Analysis

The sensitivity analysis presented in this study is to quantify variations of the ERV Credits due to the uncertainties of the REV inputs assumption: effectiveness, pressure drop, and auxiliary power inputs. These three inputs assumption may have uncertainties associated with them. Auxiliary electric power input has not been included in the sensitivity analysis. However, the ERV effectiveness and pressure drop inputs uncertainties were included in the sensitivity analysis and their impact was quantified.

6.1 Impact of ERV Effectiveness Uncertainty

The energy recovery rate for a given outdoor air flow rate and exhaust air flow rate is directly proportional to the effectiveness. The ERV effectiveness values used in this study were obtained from ERV manufacturer's data certified by AHRI. The effectiveness values were selected by matching the design flow rates of each ERV device to those in the AHRI ERV database. The design cooling and heating effectiveness values were changed by 10% to estimate the impact of the effectiveness input uncertainties on the ERV credits. Table 15 summarized reference ERV credits. Table 16 shows impacts of uncertainties of the design cooling and heating effectiveness on the ERV credit by building type and city. For instance for large hotel in Miami, Florida other input parameters being constant a 10% effectiveness increase from the design value would result in 1.32% increase in ERV credit and vice-versa.

Table 16 Impacts of effectiveness on ERV credit by building type

Cooling Effectiveness	Miami	Tampa	Orlando	Gainesville	Jacksonville	Tallahassee
Large Hospital						
67.0	7.24 ± 1.32	6.82 ± 1.28	6.76 ± 1.22	6.89 ± 1.05	6.59 ± 1.03	7.11 ± 0.96
Large Hotel						
67.0	**13.62±1.32**	14.32±1.28	13.53±1.22	14.67±1.05	14.38±1.03	15.29±0.96
Large Office						
68.0	13.45±1.33	13.30±1.26	12.96±1.27	11.85±0.89	11.88±1.05	11.37±0.91
Medium Office						
72.0	13.28 ± 1.57	13.05 ± 1.48	12.41 ± 1.44	11.18 ± 1.23	10.72 ± 1.22	10.35 ± 1.11
Standalone Retail						
70.0	11.01±1.27	11.03±0.99	10.83±0.99	13.22±0.91	13.16±0.97	14.09±0.84
Primary School						
68.0	14.88±1.62	11.25±1.19	10.78±1.12	11.63±0.94	11.16±0.96	12.86±0.95
Secondary School						
68.0	19.78±2.03	15.02±1.93	13.11±1.74	13.45±3.16	13.26±2.69	14.35±3.91
Small Office						
67.0	3.09±0.31	2.59±0.25	2.17±0.21	1.92±0.17	1.81±0.16	1.98±0.17
Small Hotel						
69.0	7.50±0.35	8.13±0.55	6.49±0.29	5.41±0.10	6.70±0.16	5.20±0.22

6.2 Impact of ERV Pressure Drop Uncertainty

ERV device installation increases the external static pressure seen by supply and return fans. The design ERV pressure drop values for the system investigated in this study were obtained from AHRI certified database. Due to design variations, ERV manufacturer's report a different pressure drop values for the same ERV size. Moreover, actual installation may result in pressure drop different from the design value. For these reasons, uncertainties in the design pressure drop across ERV devices assumed to be in the range 36.9 - 39.6 Pa. This pressure drop range corresponds to 10% change in design effectiveness. The correlation between the ERV design effectiveness and the ERV pressure drop is obtained from the 2014 Florida Energy Code. Table 17 summarizes the ERV credits change due to pressure drop uncertainties applied to the supply and return fans depending on the ERV design effectiveness values. For instance for Tampa, Florida if the average design ERV pressure drop assumption for large hotel building is increases by 36.9 Pa, then the effective ERV credit will be reduced to 13.81% (=14.32 – 0.51).

Table 17 Impacts of pressure drop on ERV credit by building type

Cooling Effectiveness	Miami	Tampa	Orlando	Gainesville	Jacksonville	Tallahassee
Large Hospital						
67.0	7.24 ± 0.49	6.82 ± 0.49	6.76 ± 0.50	6.89 ± 0.49	6.59 ± 0.50	7.11 ± 0.49
Large Hotel						
67.0	13.62 ± 0.44	**14.32 ± 0.51**	13.53 ± 0.52	14.67 ± 0.5	14.38 ± 0.53	15.29 ± 0.51
Large Office						
68.0	13.45 ± 0.6	13.3 ± 0.76	12.96 ± 0.74	11.85 ± 0.84	11.88 ± 0.78	11.37 ± 0.81
Medium Office						
72.0	13.28 ± 0.54	13.05 ± 0.57	12.41 ± 0.58	11.18 ± 0.59	10.72 ± 0.58	10.35 ± 0.59
Standalone Retail						
70.0	11.01 ± 1.86	11.03 ± 1.99	10.83 ± 2.15	13.22 ± 1.89	13.16 ± 1.91	14.09 ± 1.9
Primary School						
68.0	14.88 ± 0.70	11.25 ± 0.72	10.78 ± 0.70	11.63 ± 0.69	11.16 ± 0.69	12.86 ± 0.67
Secondary School						
68.0	19.78 ± 0.71	15.02 ± 0.72	13.11 ± 0.70	13.45 ± 0.79	13.12 ± 0.76	14.35 ± 0.76
Small Office						
67.0	3.09 ± 1.88	2.59 ± 1.89	2.17 ± 2.01	1.92 ± 2.05	1.81 ± 2.05	1.98 ± 2.07
Small Hotel						
69.0	7.5 ± 2.81	8.13 ± 2.99	6.49 ± 3.18	5.41 ± 3.44	6.7 ± 3.39	5.2 ± 3.29

Based on the effectiveness values selected for this study, the magnitude of the fan pressure adjustment due to ERV allowed per the 2014 Florida Code is about 1.0 inch w.c. (250 Pa). The pressure drop adjustment calculation due to ERV device given by equation-A1 must have been developed for medium or larger ERV devices and it is independent of ERV device size. The ERV devices used in the small office and small hotel buildings have pressure drop obtained from AHRI certified database in the range 70.0 – 150.0 Pa. This implies the 36.9 – 39.6 Pa range pressure drop uncertainties may have been large relative to their design values for the ERV devices in the small buildings. As a results of this higher ERV credits sensitivities to pressure drop were noted in the small office and hotel buildings.

6.3 Impact of ERV Inputs Uncertainty

Impacts of uncertainty of more than one input variable on an output variable can be determined by combining the individual input variables errors due to inputs uncertainties. The sensitivity of the ERV credit due to uncertainties of the design effectiveness and pressure drop can be combined using error propagation formula (JCGM, 2008) and is given by:

$$\left(\frac{\Delta E}{E}\right)=\frac{1}{E}\sqrt{\left(\frac{\partial E}{\partial P}\right)^2\cdot\left(\Delta P\right)^2+\left(\frac{\partial E}{\partial \varepsilon}\right)^2\cdot\left(\Delta \varepsilon\right)^2} \qquad 3$$

This error propagation formula assumes that the error contribution from uncertainties in effectiveness and pressure drop are independent. The combined impacts of a 10.0% uncertainty of design effectiveness and 36.0 – 39.0 Pa ERV pressure drop uncertainty are shown in Table 18.

Table 18 Impacts of effectiveness and pressure drop on ERV credit by building type and city

Cooling Effectiveness	Miami	Tampa	Orlando	Gainesville	Jacksonville	Tallahassee
Large Hospital						
67.0	7.24 ± 0.92	6.82 ± 0.83	6.76 ± 0.81	6.89 ± 0.74	6.59 ± 0.72	7.11 ± 0.71
Large Hotel						
67.0	13.62 ± 1.39	14.32 ± 1.37	13.53 ± 1.33	14.67 ± 1.16	14.38 ± 1.16	15.29 ± 1.09
Large Office						
68.0	13.45 ± 1.46	13.3 ± 1.47	12.96 ± 1.47	11.85 ± 1.22	11.88 ± 1.31	11.37 ± 1.22
Medium Office						
72.0	13.28 ± 1.66	13.05 ± 1.59	12.41 ± 1.55	11.18 ± 1.36	10.72 ± 1.35	10.35 ± 1.26
Standalone Retail						
70.0	11.01 ± 2.05	11.03 ± 2.08	10.83 ± 2.16	13.22 ± 1.96	13.16 ± 2	14.09 ± 1.97
Primary School						
68.0	14.88 ± 1.77	11.25 ± 1.39	10.78 ± 1.32	11.63 ± 1.17	11.16 ± 1.19	12.86 ± 1.16
Secondary School						
68.0	19.78 ± 2.15	15.02 ± 2.07	13.11 ± 1.88	13.45 ± 3.25	13.12 ± 2.8	14.35 ± 3.98
Small Office						
67.0	3.09 ± 1.9	2.59 ± 1.91	2.17 ± 2.02	1.92 ± 2.06	1.81 ± 2.05	1.98 ± 2.08
Small Hotel						
69.0	7.5 ± 2.84	8.13 ± 3.04	6.49 ± 3.19	5.41 ± 3.44	6.7 ± 3.4	5.2 ± 3.3

The small office, small hotel and standalone retails buildings which has constant volume fan shows a higher combined sensitivity primary due to larger uncertainty assumption for the ERV pressure drop value. This high pressure drop uncertainty assumption comes from the use of the same pressure adjustment correlation equation for all sizes of ERV device.

7 Recommendation

The ERV credits presented in Section 5.1 were based on a specific set of inputs assumption. The ERV credit adjustments is necessary when the actual design effectiveness values used in the proposed building is different from the value used to compute the ERV credits. ERV credits adjustment for every 1.0% effectiveness deviation from design value that entails a 5.5 Pa pressure drop adjustments for medium and larger size buildings and 2.75 Pa for smaller buildings are given in Table 19. The effectiveness value deviation from the design value multiplies the correction factor per unit effectiveness value in Table 19 to determine the actual ERV Credit correction factor. If the actual effectiveness is greater than the design value, the product of the effectiveness deviation from the design value and the correction factors in this table is added to the base ERV credit value, and vice versa. For instance, if the actual effectiveness of a large hospital is 70.0%, then the correction factor for Miami will be 0.42 [= (70.0-67.0) x 0.14]. The adjusted ERV credited for the large hospital building in Miami becomes 7.66% (=7.24 + 0.42). Had the actual effectiveness been 64.0%, then the adjusted ERV credit would have been reduced to 6.82% [=7.24 + (64.0-67.0) x 0.14]). The ERV credits correction shall be limited to a maximum of ±10.0% cooling effectiveness deviation from that of the design value.

Table 19 Recommended ERV credits for code compliance by building type and city

Cooling Effectiveness	Miami	Tampa	Orlando	Gainesville	Jacksonville	Tallahassee
Large Hospital						
67.0	**7.24 ± 0.14**	6.82 ± 0.12	6.76 ± 0.12	6.89 ± 0.11	6.59 ± 0.11	7.11 ± 0.11
Large Hotel						
67.0	13.62 ± 0.21	14.32 ± 0.20	13.53 ± 0.20	14.67 ± 0.17	14.38 ± 0.17	15.29 ± 0.16
Large Office						
68.0	13.45 ± 0.21	13.3 ± 0.22	12.96 ± 0.22	11.85 ± 0.18	11.88 ± 0.19	11.37 ± 0.18
Medium Office						
72.0	13.28 ± 0.23	13.05 ± 0.22	12.41 ± 0.22	11.18 ± 0.19	10.72 ± 0.19	10.35 ± 0.17
Standalone Retail						
70.0	11.01 ± 0.19	11.03 ± 0.18	10.83 ± 0.18	13.22 ± 0.17	13.16 ± 0.18	14.09 ± 0.17
Primary School						
68.0	14.88 ± 0.26	11.25 ± 0.20	10.78 ± 0.19	11.63 ± 0.17	11.16 ± 0.17	12.86 ± 0.17
Secondary School						
68.0	19.78 ± 0.32	15.02 ± 0.30	13.11 ± 0.28	13.45 ± 0.48	13.12 ± 0.41	14.35 ± 0.59
Small Office						
67.0	3.09 ± 0.15	2.59 ± 0.15	2.17 ± 0.15	1.92 ± 0.15	1.81 ± 0.15	1.98 ± 0.16
Small Hotel						
69.0	7.5 ± 0.21	8.13 ± 0.23	6.49 ± 0.23	5.41 ± 0.25	6.7 ± 0.25	5.2 ± 0.24

For simplicity of the ERV credit application, the correction factors and the base ERV credits can be organized by building type and climate zones. The results of the five climate 2A cities were averaged to come up with a single representative value. Table 20 provided the base ERV credits and the ERV correction factors for every 1% cooling effectiveness deviation from the design values by building type and climate zones. For example if the actual cooling effectiveness of a large hospital is 70.0%, then the ERV credits correction factor for climate zone 1A and 2A will be 0.42(=3.0x0.14) and 0.33 (=3.0x0.11), respectively. The adjusted ERV credit for the large hospital building will be 7.66% (=7.24 + 0.42) for climate zone 1A, and 7.16% (=6.83 + 0.33) for climate Zone 2A. Had the actual effectiveness been 64%, then the adjusted ERV credit would have been 6.82% (=7.24 - 0.42) for climate zone 1A, and 6.50% (=6.83 - 0.33) for climate zone 2A.

Table 20 Recommended ERV credits for code compliance by building and climate zones

Building Types	Design Cooling Effectiveness, %	ERV Credit Climate Zone 1A	ERV Credit Correction	ERV Credit Climate Zone 2A	ERV Credit Correction
Large Hospital	67.0	7.24	0.14	6.83	0.11
Large Hotel	67.0	13.62	0.21	14.44	0.18
Large Office	68.0	13.45	0.21	12.27	0.20
Medium Office	72.0	13.28	0.23	11.54	0.20
Standalone Retail	70.0	11.01	0.19	12.47	0.17
Primary School	68.0	14.88	0.26	11.54	0.18
Secondary School	68.0	19.78	0.32	13.81	0.41
Small Office	67.0	3.09	0.15	2.09	0.15
Small Hotel	69.0	7.50	0.21	6.39	0.24

The ERV credits determined vary by building type, HVAC system type, and weather location. Moreover, the ERV credits may also vary by effectiveness, pressure drop and auxiliary electric power inputs assumption. Due to similarity in operating hours per day, inputs assumption, and HVAC system types, the medium and large office buildings have similar ERV credits. The small office building has a constant volume packaged HVAC system type, which is different from that of the other two office buildings. In addition to the HVAC system type difference, the small office buildings has lower design outdoor air fraction, lower fan efficiency, and has lower part-load performance. For these reasons, the ERV credit of the small office is about 4 times less than that of the large and medium office buildings. All buildings with constant volume HVAC systems: small office, small hotel and standalone retail buildings demonstrated lower annual HVAC energy savings and very high sensitivity to the ERV fan pressure drop change. This is primarily caused by the constant fan energy penalty added due to the ERV pressure drop added. The other commercial building types: Warehouse, Retail Strip Mall, Restaurant Sit Down, Restaurant Fast Food, Out Patient Health Care, Apartment Mid Rise and Apartment High Rise that were not covered in this project may need separate study, instead of approximately mapping to the ERV credits in Table 20.

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8 Appendix

The appendix section summarizes input assumptions for every ERV device added for each system type for the nine commercial buildings analyzed. The input assumptions include:

- design supply air flow rates
- energy and heat recovery device types (ERV, HRV)
- auxiliary electric power specified for each device
- pressure drop across the device
- fan total efficiency
- fan motor efficiency
- cooling design sensible and latent effectiveness at 100% capacity
- cooling sensible and latent effectiveness at 75% capacity
- heating design sensible and latent effectiveness at 100% capacity
- heating sensible and latent effectiveness at 75% capacity
- fan pressure adjustment due to ERV device

Fan Pressure Adjustment

Fan pressure adjustments due to ERV device are allowed per the 2014 Florida Energy Code (*Florida Building Code, 2014*). The fan pressure adjustment for energy wheel and plate heat exchanger is given by:

$$\Delta P = 2.2 \cdot \varepsilon - 0.5 \qquad \text{A1}$$

Where

ΔP = pressure drop adjustment allowed for supply and return air stream fans, (inch w.c.)

ε = the ERV cooling and heating design effectiveness, (-)

For every 1.0% change in design effectiveness the corresponding change in ERV pressure drop is about 0.022 inch w.c. (5.5 Pa).

The pressure adjustment for ERV device calculated using equation A1 (*Florida Building Code, 2014*) seems slightly higher than those obtained from AHRIC certified database; hence, the actual pressure drop obtained from AHRI database were used, instead.

Table-A1 Large office building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	ERV/HRV Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV_BOT OA HR	2.538	5,378	WHEEL	318.7	237.5	0.60	0.825	249.0
VAV_MID OA HR	25.380	53,778	WHEEL	3187.0	237.5	0.60	0.825	249.0
VAV_TOP OA HR	2.538	5,378	WHEEL	318.7	237.5	0.60	0.825	249.0
DC_BOT OA HR	0.016	33	PLATE	0.0	70.0	0.55	0.820	243.5
DC_MID OA HR	0.156	331	PLATE	0.0	70.0	0.55	0.820	243.5
DC_TOP OA HR	0.016	33	PLATE	0.0	70.0	0.55	0.820	243.5
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV_BOT OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
VAV_MID OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
VAV_TOP OA HR	0.68	0.60	0.73	0.67	0.68	0.6	0.73	0.67
DC_BOT OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
DC_MID OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
DC_TOP OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33

Table-A2 Medium office building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	ERV/HRV Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV_BOT OA HR	1.102	2,335	Wheel	256.5	212.5	0.55	0.820	271.0
VAV_MID OA HR	1.195	2,532	Wheel	256.5	212.5	0.55	0.820	271.0
VAV_TOP OA HR	1.195	2,532	Wheel	256.5	212.5	0.55	0.820	271.0
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV_BOT OA HR	0.72	0.64	0.76	0.68	0.72	0.64	0.77	0.68
VAV_MID OA HR	0.72	0.64	0.76	0.68	0.72	0.64	0.77	0.68
VAV_TOP OA HR	0.72	0.64	0.76	0.68	0.72	0.64	0.77	0.68

Table-A3 Small office building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	ERV/HRV Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
PSZ-AC:1_OA HR	0.065	137	Plate	0.0	70.0	0.55	0.820	243.5
PSZ-AC:2_OA HR	0.049	104	Plate	0.0	70.0	0.55	0.820	243.5
PSZ-AC:3_OA HR	0.029	62	Plate	0.0	70.0	0.55	0.820	243.5
PSZ-AC:4_OA HR	0.049	104	Plate	0.0	70.0	0.55	0.820	243.5
PSZ-AC:5_OA HR	3E-02	62	Plate	0.0	70.0	0.55	0.820	243.5
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
PSZ-AC:1_OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
PSZ-AC:2_OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
PSZ-AC:3_OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
PSZ-AC:4_OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
PSZ-AC:5_OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33

Table-A4 Large hotel building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV WITH REHEAT HR	9.157	19,403	WHEEL	318.7	212.5	0.60	0.855	232.5
FLR_3_DOAS HR	2.051	4,346	WHEEL	256.5	250.0	0.55	0.825	287.5
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV WITH REHEAT HR	0.65	0.61	0.72	0.66	0.65	0.61	0.72	0.66
FLR_3_DOAS HR	0.75	0.69	0.79	0.74	0.75	0.69	0.79	0.74

Table-A5 Small hotel building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
FrontOffice OA HR	0.35332	749	PLATE	0.0	67.5	0.55	0.820	243.5
FRONTLOUNGE OA HR	0.85933	1,821	PLATE	0.0	147.5	0.55	0.820	249.0
MEETINGROOM OA HR	0.39788	843	PLATE	0.0	112.5	0.55	0.820	265.5
EMPLGE_RESTRM OA HR	0.73220	1,551	PLATE	0.0	72.5	0.55	0.820	254.5

ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
FrontOffice OA HR	0.67	0.32	0.70	0.37	0.67	0.28	0.70	0.33
FRONTLOUNGE OA HR	0.68	0.44	0.70	0.48	0.68	0.40	0.70	0.44
MEETINGROOM OA HR	0.70	0.42	0.73	0.47	0.72	0.34	0.74	0.37
EMPLGE_RESTRM OA HR	0.69	0.42	0.72	0.48	0.69	0.39	0.72	0.45

Table-A6 Standalone retail building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	ERV/HRV Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
PSZ-AC:1 OA HR	0.232	491	Plate	0.0	167.5	0.55	0.820	243.5
PSZ-AC:2 OA HR	1.890	4,005	Plate	0.0	162.5	0.55	0.820	265.5
PSZ-AC:3 OA HR	0.178	377	Plate	0.0	80.0	0.55	0.820	249.0
PSZ-AC:4 OA HR	0.178	377	Plate	0.0	80.0	0.55	0.820	249.0

ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
PSZ-AC:1 OA HR	0.67	0.59	0.71	0.64	0.67	0.49	0.71	0.55
PSZ-AC:2 OA HR	0.71	0.52	0.75	0.59	0.71	0.43	0.75	0.50
PSZ-AC:3 OA HR	0.69	0.57	0.72	0.62	0.67	0.52	0.70	0.57
PSZ-AC:4 OA HR	0.69	0.57	0.72	0.62	0.67	0.52	0.70	0.57

Table-A7 Large hospital building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV_1 OA HR	5.408	11,459	WHEEL	318.7	237.5	0.60	0.840	249.0
ICU OA HR	2.076	4,398	PLATE	0.0	182.5	0.55	0.825	287.5
PATRMS OA HR	4.492	9,519	WHEEL	318.7	237.5	0.60	0.840	249.0
VAV_ER OA HR	0.925	1,960	PLATE	0.0	150.0	0.55	0.820	249.0
VAV_OR OA HR	2.180	4,619	PLATE	0.0	182.5	0.55	0.820	202.3
VAV_LABS OA HR	0.619	1,311	WHEEL	256.5	250.0	0.55	0.820	207.8
VAV_2 OA HR	5.599	11,864	WHEEL	318.7	237.5	0.60	0.840	249.0
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV_1 OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
ICU OA HR	0.60	0.0	0.61	0.0	0.59	0.0	0.59	0. 0
PATRMS OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
VAV_ER OA HR	0.69	0.0	0.70	0.0	0.67	0.0	0.68	0.0
VAV_OR OA HR	0.60	0.0	0.61	0.0	0.59	0.0	0.59	0.0
VAV_LABS OA HR	0.76	0.70	0.80	0.75	0.76	0.70	0.80	0.75
VAV_LABS OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67

Table-A8 Primary school building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV_POD_1 OA HR	3.647	7,726	Wheel	318.7	237.5	0.60	0.840	249.0
VAV_POD_2 OA HR	3.592	7,610	Wheel	318.7	237.5	0.60	0.840	249.0
VAV_POD_3 OA HR	3.199	6,778	Wheel	318.7	212.5	0.60	0.840	232.5
VAV_OTHER OA HR	2.235	4,736	Wheel	256.5	125.0	0.55	0.820	276.5
PSZ-AC_2:5 OA HR	0.897	1,900	Plate	0.0	150.0	0.55	0.820	249.0
PSZ-AC_2:7 OA HR	1.488	3,153	Plate	0.0	247.5	0.55	0.820	262.8

ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV_POD_1 OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
VAV_POD_2 OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
VAV_POD_3 OA HR	0.65	0.61	0.72	0.66	0.65	0.61	0.72	0.66
VAV_OTHER OA HR	0.74	0.63	0.76	0.70	0.72	0.63	0.75	0.69
PSZ-AC_2:5 OA HR	0.69	0.0	0.70	0.0	0.67	0.0	0.68	0.0
PSZ-AC_2:7 OA HR	0.72	0.0	0.72	0.0	0.69	0.0	0.70	0.0

Table-A9 Secondary school building ERV device inputs assumption

ERV Name	Nominal Supply Air Flow Rate [m3/s]	Nominal Supply Air Flow Rate [cfm]	ERV/HRV Device Type	ERV/HRV Auxiliary Power, W	ERV/HRV ΔP, Pa (AHRI 1060)	Fan Total Efficiency	Fan Motor Efficiency	Fan ΔP Adjustment, Pa (ASHRAE 90.1)
VAV_POD_1 OA HR	8.594	18,210	WHEEL	318.7	212.5	0.60	0.855	232.5
VAV_POD_2 OA HR	8.563	18,144	WHEEL	318.7	212.5	0.60	0.855	232.5
VAV_POD_3 OA HR	9.493	20,114	WHEEL	318.7	212.5	0.60	0.855	232.5
VAV_OTHER OA HR	4.289	9,089	WHEEL	318.7	237.5	0.60	0.840	249.0
PSZ-AC_1:5 OA HR	3.011	6,380	WHEEL	318.7	250.0	0.60	0.840	287.5
PSZ-AC_2:6 OA HR	1.902	4,030	WHEEL	256.5	125.0	0.55	0.820	276.5
PSZ-AC_3:7 OA HR	4.065	8,614	WHEEL	318.7	250.0	0.60	0.840	287.5
PSZ-AC_5:9 OA HR	2.948	6,246	WHEEL	318.7	250.0	0.55	0.840	287.5
ERV Name	100% Heating ε_s	100% Heating ε_l	75% Heating ε_s	75% Heating ε_l	100% Cooling ε_s	100% Cooling ε_l	75% Cooling ε_s	75% Cooling ε_l
VAV_POD_1 OA HR	0.65	0.61	0.72	0.66	0.65	0.61	0.72	0.66
VAV_POD_2 OA HR	0.65	0.61	0.72	0.66	0.65	0.61	0.72	0.66
VAV_POD_3 OA HR	0.65	0.61	0.72	0.66	0.65	0.61	0.72	0.66
VAV_OTHER OA HR	0.68	0.60	0.73	0.67	0.68	0.60	0.73	0.67
PSZ-AC_1:5 OA HR	0.75	0.69	0.79	0.74	0.75	0.69	0.79	0.74
PSZ-AC_2:6 OA HR	0.74	0.63	0.76	0.70	0.72	0.63	0.75	0.69
PSZ-AC_3:7 OA HR	0.75	0.69	0.79	0.74	0.75	0.69	0.79	0.74
PSZ-AC_5:9 OA HR	0.75	0.69	0.79	0.74	0.75	0.69	0.79	0.74